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A REVISION OF THE STRUCTURE OF THE HEAD, MOUTH-PART AND SALIVARY GLANDS OF *GLOSSINA PALPALIS* ROB.-DESV.

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(With Plates XVIII–XXII, containing Figs. 1–32, and Figs. I–XI in the Text.)*

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INTRODUCTION.

THE structure of the head and especially of the mouth-parts of these economically very important flies has been studied by many observers. The first very brief remarks on the proboscis were made by Wiedemann (1830), in his original description of the genus *Glossina*. He pointed out that the proboscis is almost as long as the thorax, and setiform and triangular in its basal part, the palps almost as long as the proboscis and horizontal. In the same year, Robineau-Desvoidy (1830) described another species of tsetse-fly, *Glossina palpalis*, but under the generic name *Nemorphina*, which became a synonym of *Glossina*. In his diagnosis of the genus, he gave an even shorter description of the proboscis which he believed was not adapted for sucking blood.

Macquart (1835) indicated the presence of the labrum and the hypopharynx, and also pointed out that in the structure of the proboscis and the antennae *Glossina* approaches *Stomoxys* and *Haematobia*. In another work (1843) he expressed the opinion that the tsetse-flies are not blood-suckers but feed upon the nectar of flowers. He was led to this erroneous conclusion by the fine structure and flexibility of the proboscis and its protection by the palps.

* Note that *Plate* figures are cited in *Arabic* numbers and *Text* figures in *Roman* numbers throughout. Ed.

Westwood (1850) described the proboscis as "a slender, horny seta or compound bristle. . . dilated at the base into a large oval bulbous horny lobe." He dissected out of the groove of the upper side of the proboscis two very delicate styles, but did not homologise them, nor indicate their function.

The bite of the tsetse-fly and its effect on cattle was described by Livingstone (1857). He attributed the symptoms to the "poison in the blood," the "germ" of which is introduced from the proboscis during the sucking of blood. He came to the conclusion that the "poison germ" is contained in the basal bulbous part of the proboscis.

Kirk (1865) described the biting apparatus as composed of four parts, of which the two lateral represent the palps and serve for the protection of the proboscis. This consists of a straight, horny bristle slightly dilated at the apex and expanded into a large body of cordate form at the base. The upper surface of this is grooved and contains a slender style convex above and deeply concave beneath. According to him this style is the biting instrument. He denies the existence of a tongue described by Macquart. He dissected the dilated basal part of the proboscis and pointed out that it did not contain poisonous glands or poison germs, as suggested by Livingstone, but had muscle bundles arising from a common tendon. He attributed the irritation produced by the bite to "irritant matter," which according to him "produces local congestion and thus facilitates the sucking of blood."

No further important contribution to the anatomy of the mouth-parts was made till Stuhlmann (1902) published a short paper illustrated by a few drawings.

Wesche (1903) wrote a very short account in which he incorrectly interpreted the homology of the maxillary palps and stated his belief that the mandibles and the maxillae had been absorbed into the labium.

Hansen (1903) wrote a detailed account on the structure of the sclerotised parts of the proboscis and compared them with those of *Stomoxys calcitrans* L. He described the main part of the armature of the labella and pointed out that the teeth are the chief piercing instruments.

Sander (1905) made a compilation from the work of Stuhlmann and Hansen and reproduced several drawings from the papers of these authors.

Stuhlmann (1905) added very little to his previous description and that of Hansen.

Giles (1906) misunderstood the structure of the anterior part of the proboscis, attributing the piercing action exclusively to the labrum. His description of the other parts of the proboscis is very incomplete.

Stephens and Newstead (1906) minutely described the anterior regions of the proboscis, but did not homologise the parts, and owing to the absence of properly fixed material they could not study the internal structure.

Stuhlmann (1907) published a fairly complete account of the anatomy of *Glossina*; his description of the head capsule and the internal structure of the labium is, however, incomplete in many respects.

A more recent paper was written by Cragg (1913). This author homologised the different parts of the proboscis with those of the other blood-sucking Muscidae. But owing to the very limited material at his disposal, he could not elucidate several points in the anatomy and the mechanism of the proboscis.

The examination of the above-mentioned literature shows that up to the present time, when the importance of these flies as vectors of trypanosomal diseases is fully realised, there is no complete work on the structure in question. Having received the necessary material, I therefore decided to reinvestigate the structure.

For section cutting the ordinary paraffin method has been found quite satisfactory, and double imbedding was used only in a few cases. All the sections were stained with Mayer's acid haemalum and counter-stained with an alcoholic solution of eosin. For the material of *Glossina palpalis* Rob.-Desv., collected near Entebbe, Uganda, I am indebted to Dr C. A. Hoare and to Dr J. M. Wallace.

The head and mouth-parts of *G. palpalis* Rob.-Desv. were compared with those of the following species of the genus: *G. fusca* Walk., *G. brevipalpis* Newst. and *G. morsitans* Westw. It has been found that the parts have practically the same structure and differ in their dimensions only.

THE HEAD CAPSULE.

The head capsule of the genus *Glossina* belongs to the muscid type. In its general appearance it differs, but only in small details, from the head of the other Muscidae, and has practically the same structure as that of the genus *Stomoxys*. The head occupies the vertical position with regard to the longitudinal body axis, with the mouth-parts, which are concealed between the palps, directed forwards. When viewed frontally, the head is rounded, the compound eyes occupying nearly the whole of the lateral parts (Fig. I A). Immediately above the antennae and extending ventrally along each side of the narrow parts of the vertex, as far as the gena (*ge.*), there is a very conspicuous inverted **V**-shaped slit, the ptilinal suture (*pt.s.*). This suture is formed by the edge of a special invagination of the vertex, a frontal sac, or the ptilinum (*pt.*). The ptilinum is inverted and lies inside the head in the adult fly. It is formed of a thick membrane the surface of which is beset with sclerotised and darkly pigmented spines (Fig. III A, B and C). In the middle part of the ptilinum the spines are pyramidal and as long as broad at the base (Fig. III A), but towards the ptilinal suture and in the narrow ventral parts of the sac the spines gradually become much longer (Fig. III B). The dorsal part of the ptilinal suture, immediately above the antennae, is continuous with a broad membranous stripe, the mediovertex (*mdv.*), the frontalia, or the frontal stripe of the dipterologists. The mediovertex has practically the same structure as the ptilinal membrane; its surface is wrinkled and bears sclerotised, pigmented scales. The scales are very narrow, except at the ptilinal suture, where they are much broader and greatly resemble those of the

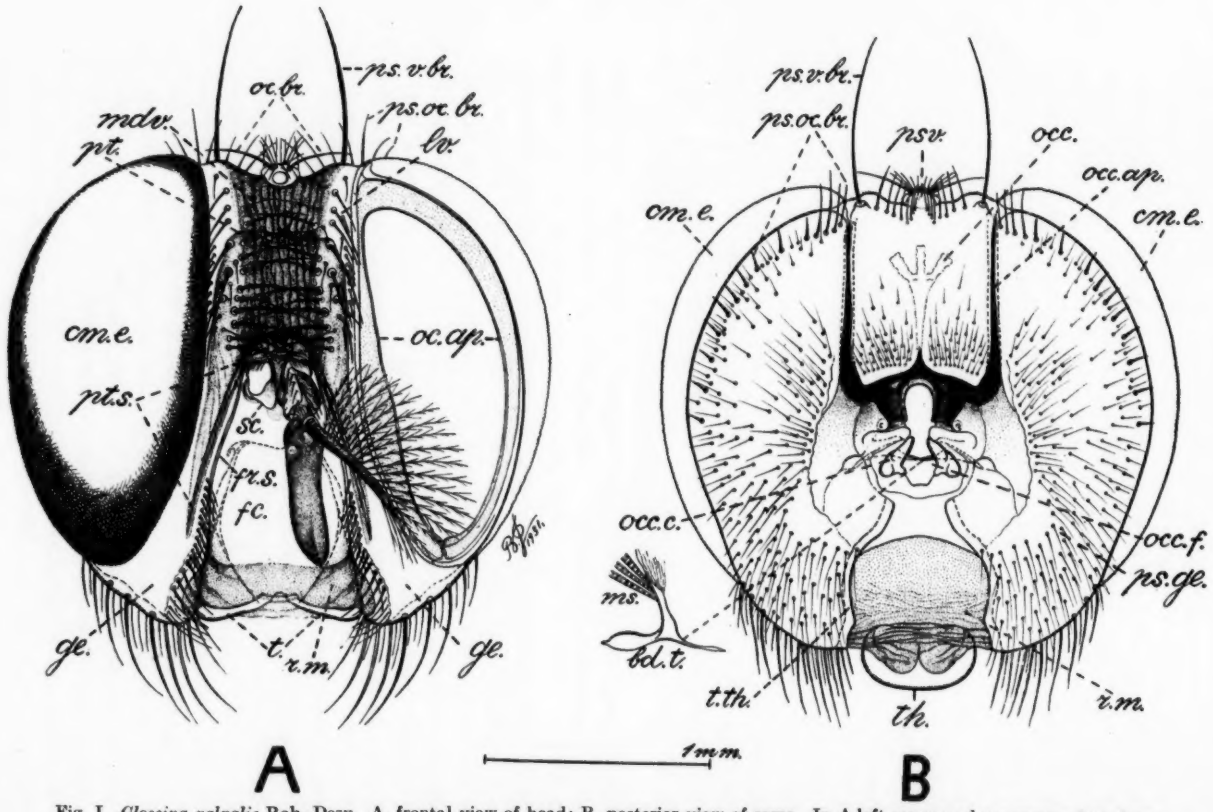

Fig. I. *Glossina palpalis* Rob.-Desv. A, frontal view of head; B, posterior view of same. In A left compound eye removed to show ocular apodeme (*oc.ap.*) and right antennal segment removed to show scape (*sc.*).

ptilinum. I have compared the structure of the mediovertex with that of *Musca domestica*, but I could not find the dark median line, which, according to Patton and Evans (1929), indicates the position of the obsolete epicranial suture in *Musca domestica*. This line is also absent in *Stomoxys calcitrans* L. The function of the ptilinum of *Glossina* was observed by Stuhlmann (1907) and also by Newstead (1924). It is exactly the same as in the other Diptera Schizophora. At the moment of the emergence of the fly from the puparium, the ptilinum becomes inflated by abdominal pressure and breaks off the last larval skin. By its rhythmical pulsation it also helps the fly to pass through the earth or decaying humus in which the larva concealed itself before pupation. My own observation on the head of the Muscidae during hatching showed that the dorsal surface of the inflated ptilinum is continuous with the mediovertex, the membrane of which is greatly extended. But immediately after the hatching of the fly, the ptilinum is inverted inside the head, and the membrane of the mediovertex gathers into the folds which extend along this part of the vertex from the dorsal edge of the ptilinal suture. Posteriorly the mediovertex extends as far as the post-vertical bristles (*ps.v.br.*) surrounding the frontal and the lateral parts of the postvertex, or the ocellar triangle (*psv.*). This region of the vertex is convex, sclerotised and darkly pigmented. It bears three ocelli, which are seen as clear rounded spots, two of them in the posterior part and one, which is slightly larger, in front. Between the ocelli arise two strong ocellar bristles (*oc.br.*). Besides these, there are many much smaller bristles in the middle and the posterior part.

The lateral regions of the vertex, which are limited externally by the compound eyes and internally by the mediovertex and the ptilinal suture, are the laterovertices (*lv.*). The dorsal part of each laterovertex is strongly sclerotised and very darkly pigmented, while its ventral part, which is between the compound eye and the ptilinal suture, is of a light yellowish colour in specimens cleared in caustic potash. The dorsal part of the laterovertex bears a row of convergent bristles along its inner margin. These bristles bend over the mediovertex and cross with those of the other laterovertex. There are besides a few very strong bristles in the middle and several small ones close to the compound eye. Each laterovertex extends ventrally as far as the end of the ptilinal suture, where it merges into the genae (*ge.*). There is no suture separating these regions of the head from each other. The gena bears a row of very strong and long bristles along its ventral margin. There is also a row of moderately strong bristles along the inner margin to which is attached the rostrum membrane (*r.m.*). This row of bristles is continuous dorsally along the narrow part of the vertex between the ptilinal and the frontal suture (*fr.s.*), as far as the middle of the frontal part of the head, or the fronto-clypeus (*fc.*).

The fronto-clypeus is formed by the fusion of two unpaired sclerites—the front and the clypeus. Dipterologists call it the front, or the interfaciala, applying the term clypeus to the parts which are named tormae (*t.*) in this paper. The fronto-clypeus represents a deeply concave, sclerotised plate which

projects posteriorly inside the head. Its dorsal part is rounded and very weakly sclerotised; it is attached dorsally to the ptilinum. There are present two openings, each of which is surrounded by a sclerotised ring to which is attached the first antennal segment, or the scape (*sc.*). In the deep cavity of

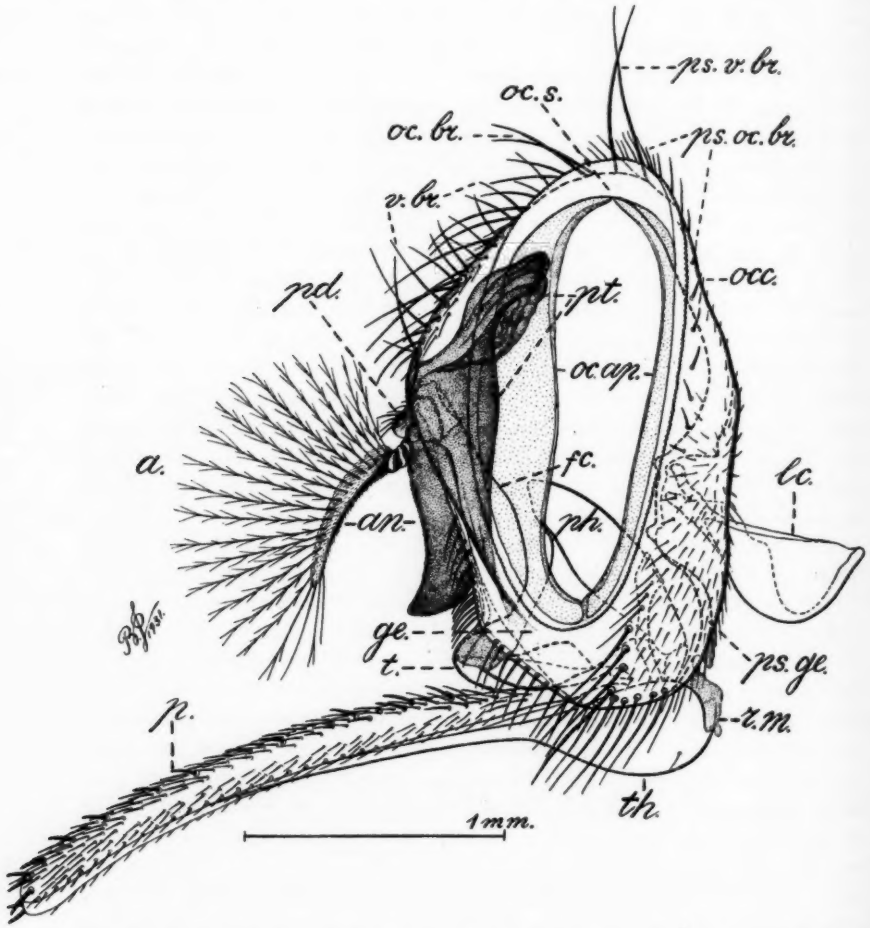

Fig. II. *Glossina palpalis* Rob.-Desv., lateral view of head. Compound eye removed to show ocular apodeme and position of pharynx (*ph.*).

the fronto-clypeus lie the greatly enlarged third antennal segments. The ventral part of the fronto-clypeus is much broader than the dorsal and projects anteriorly; to its margin is attached the rostrum membrane, which connects it with the tormae (*t.*) ventrally and the genae laterally. The fronto-clypeus is separated from the vertex by the frontal suture (*fr.s.*), which represents the

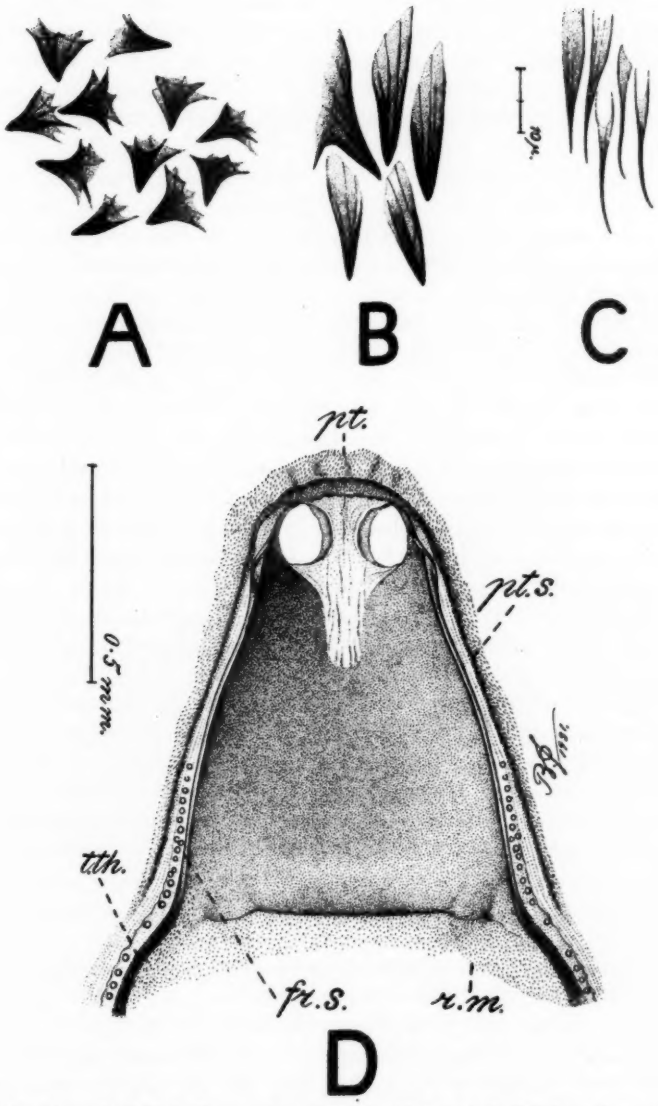

Fig. III. *Glossina palpalis* Rob.-Desv., spines; A, from middle part of ptilinal membrane; B, from lateral part of same; C, from dorsal part of ptilinal suture; D, fronto-clypeus.

greatly modified arms of the epicranial suture. This suture extends dorsally along each side of the fronto-clypeus as far as the sclerotised ring-shaped structure to which the first antennal segment is attached, whereas ventrally it is continuous with a thick apodeme of the inner margin of each gene and the postgena. These apodemes, or the tentorial thickenings (*t.th.*), apparently represent the greatly modified anterior arms of the tentorium of the lower Diptera.

The posterior surface of the head is rather flat, but round the occipital foramen it is deeply concave. The occipital foramen (*occ.f.*) is formed by a dorsal and a ventral arch; between these arches on each side of the foramen is attached the occipital condyle (*occ.c.*), to the posterior end of which articulates the latero-cervical sclerite (*lc.*). These latero-cervical sclerites occupy the lateral position in the neck, being connected dorsally and ventrally by the neck membrane arising at the margin of the occipital foramen. The dorsal half of the posterior surface of the head is the occiput (*occ.*). This region extends ventrally to an imaginary transverse line drawn through the middle of the occipital foramen. Ventrally to this line lie the postgenae (*psge*). They are fused together below the occipital foramen, while in the ventral part of the head they are widely separated from each other by the rostrum membrane. The occiput and the postgenae bear numerous thin bristles directed radially from the concave part which surrounds the occipital foramen. This concavity, which encloses the neck, is devoid of bristles. Behind each compound eye the occiput has a row of post-ocular bristles (*ps.oc.br.*). These bristles are moderately long in the dorsal part, whereas in the lateral they are very much shorter but thicker.

Besides the tentorial thickenings, which have already been described together with the frontal suture and the genae, there are two very thick and darkly pigmented occipital apodemes (*occ.ap.*), the dorso-lateral thickenings of Peterson (1916). They project inside the head capsule and extend from the posterior corners of the vertex to the occipital foramen, there they bend inwards forming together a very thick, darkly pigmented projection round the dorsal arch. On the external surface of the head their position is indicated by very thin depressed lines. In *Calliphora*, *Musca* and *Stomoxys* these apodemes have exactly the same structure as those of *Glossina*.

Round the edge of the compound eye the head capsule infolds, forming a projection which is called the ocular sclerite (*oc.s.*). The dorsal part of this sclerite, which invaginates from the vertex, is very broad, while the rest of it is very narrow. From this sclerite arises a very thin structure, or the ocular apodeme (*oc.ap.*). This serves as a support for the cone of the compound eye, which is composed of ammatidia.

In many Diptera there is another sclerotised structure inside the head, which was described by Peterson (1916), under the name of the body of the tentorium (Fig. I B). The body of the tentorium of *Glossina* resembles that of *Musca* and *Calliphora*. It serves as a support for the cephalic ganglion and is

composed of two very small sclerites (*bd.t.*). Each of these sclerites is attached to the internal surface of the head not far from the lateral edge of the occipital foramen. It gives off two processes; a dorsal and a lateral. From the dorsal processes arise membranous filaments which surround the latero-anterior parts of the cephalic ganglion. The lateral processes are fused together in front of the occipital foramen, forming a curved rod, on which rests the postero-ventral part of the cephalic ganglion.

THE ANTENNAE.

(Fig. IV.)

The antennae of *Glossina* belong to the muscid type; structurally they are very similar to those of *Musca* and *Stomoxys*. Each antenna consists of six segments, of which the third segment is greatly enlarged. It has three sensoria, or olfactory pits, and bears the arista which includes three remaining segments.

The first antennal segment, or the scape (*sc.*), is more or less ring-shaped. Its dorsal part is narrow and bears a few setae, while the ventral part is broad and projects antero-ventrally as a triangular flap (Fig. I A). The scape is attached by a very narrow membrane to the ring-shaped structure of the dorsal part of the fronto-clypeus. Through the scape passes the antennal nerve (*an.n.*) and the trachea (*tr.*). It also serves for the attachment of the muscles of the second antennal segment or the pedicle.

The pedicle (*pd.*) is cone-shaped and is movably attached by a membranous joint to the anterior edge of the scape. The dorsal surface of the pedicle is divided by a very distinct furrow (*fu.*) into two halves which bear many moderately strong setae. There are also a few very small setae on the outer side of its anterior edge. The furrow of the dorsal surface of this segment is formed by a special invagination. This invagination projects anteriorly as a toothed process (*to.p.*), which serves for the attachment of the third antennal segment. Immediately behind this process, on the dorso-anterior surface of the projection, there is an opening through which the antennal nerve and the trachea pass into the third antennal segment (Fig. IV E). In the cavity of the pedicle lies the so-called organ of Johnston (*o.j.*). This organ was described first in the pedicle of the antenna of the mosquito (*Culex*) by Johnston (1855). Subsequently it has been found in all the principal orders of insects, and some writers regard it as an auditory organ. The known facts concerning the structure of this organ in insects generally were fully discussed by Snodgrass (1926). In *Glossina* it is briefly as follows: The posterior part of the cavity of the pedicle is occupied by a mass of elongated sense cells which have a very large round nucleus. By one end these cells are connected with the main antennal nerve, whereas the other end gives off a long scolopala, or the sense rod. These rods form a sort of cylindrical sheath round the antennal nerve, which passes through the pedicle to the flagellum; they end in the circular membrane connecting the anterior opening of the pedicle with the third antennal segment. Each rod is surrounded by very long enveloping cells and

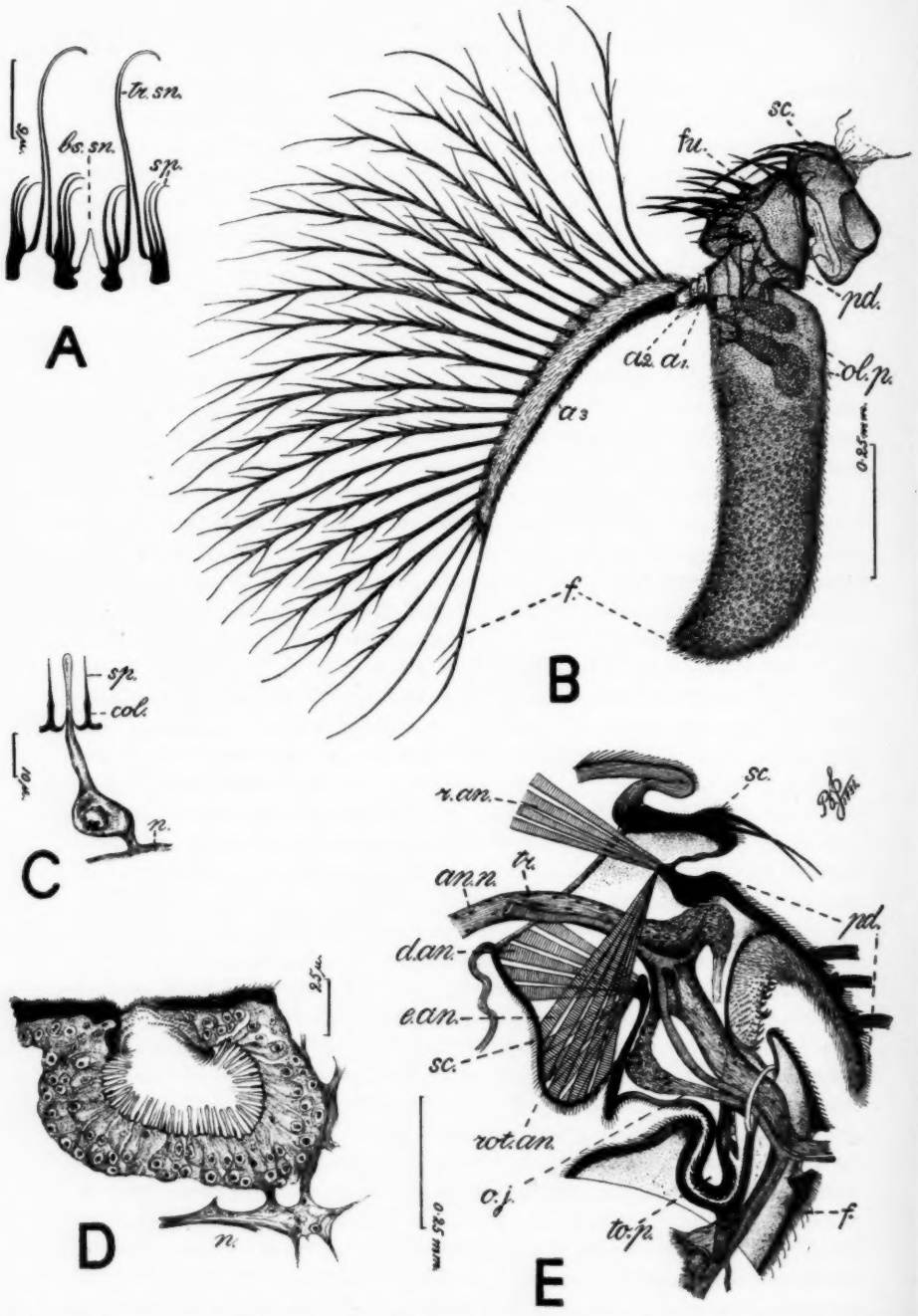

Fig. IV. *Glossina palpalis* Rob.-Desv. A, sensillae and spines from first segment of flagellum; B, right antenna; C, sensilla and nerve cells from olfactory pit; D, olfactory pit; E, left half of scape (*sc.*) and pedicle *pd.*) showing antennal muscles, organ of Johnston and attachment of flagellum (*f.*).

has a round terminal enlargement which is seen as a darkly stained dot (Fig. IV E).

The third antennal segment, or the first segment of the flagellum (*f.*), is the largest[1]. It hangs down, being partly concealed in the concave fronto-clypeus. Its lower anterior end projects forward. The surface of this segment bears numerous curved spines (*sp.*) and trichoid sensillae (*tr.sn.*). These sensillae are very much longer than the spines and are strongly curved in their distal part. Besides, there are many very short sensillae broad at the base, the basio-conical sensillae (*bs.sn.*) in the middle and anterior parts. These sensillae were described by all the authors as the sense pits, or the circular pores (Fig. IV A). The posterior part of this segment has a deep socket in which is enclosed the toothed process of the pedicle (*to.p.*). The external surface of the socket bears hook-shaped spines, while the internal gives off a weakly sclerotised process which projects inside the segment. In the dorsal part of the anterior surface of the third segment is attached the three-segmented arista (*a.*). Immediately below the first segment of the arista there is an opening which leads into two sacular sensoria, or the olfactory pits (*ol.p.*). These pits are oblong, the upper one slightly longer than the lower. The third olfactory pit is ovoid; it has an opening on the surface facing the other antenna. The morphology of these organs was described by Smith (1919) in several families of Diptera. The olfactory pits of *Glossina* are formed by a sacciform invagination of the integument (Fig. IV D). From the wall of this invagination arise numerous thin-walled sensillae. At their base they are surrounded by a sort of sclerotised collar (*col.*), which bears the protecting spines (*sp.*). Each sensilla is connected with a pyriform sense cell which has a big, rounded nucleus in its broadest part. The sense cell unites with a branch of the antennal nerve and its cytoplasm extends inside the sensilla (Fig. IV C). The wall of the olfactory pit near the opening is ridged and bears numerous, outwardly directed spines which protect it from the penetration of foreign particles.

The first two segments of the arista are very small, ring-shaped and covered with thin, curved spines, whereas the third segment is very long, tapering and slightly curved. From its surface arise many spines; these are very much longer and much more numerous on the dorsal surface, which bears 22 or 23 very long, curved, branching hairs. The peculiar development of these hairs in *Glossina* and their connection with the nervous system shows that this segment has also an important sensory function.

THE MUSCLES OF THE ANTENNAE.

All the muscles of the antenna are inserted into the pedicle and only one of them arises inside the head. The movement of the flagellum depends entirely upon the movement of the pedicle.

[1] The flagellum includes all the segments of the antenna of Diptera, except the scape and the pedicle.

The retractor of the antenna (*r.an.*). This muscle arises from the laterovertex and passes through the scape, being inserted into a short process of the dorsal part of the posterior border of the pedicle.

The elevator of the antenna (*e.an.*). This muscle arises from the ventral part of the scape and is inserted near the retractor of the antenna.

The depressor of the antenna (*d.an.*). This muscle arises from the ventral part of the scape, near its posterior border. It is inserted into the ventral part of the posterior border of the pedicle.

The rotator of the antenna (*rot.an.*). This muscle arises from the latero-ventral part of the scape, its bands being inserted into the ventral part of the posterior border of the pedicle.

The mouth-part. General account.

(Fig. V.)

The proboscis of *Glossina* is composed of the same parts as the proboscis of the blood-sucking Muscidae, but the structure of different parts shows much closer resemblance to those of the Hippoboscidae. The proboscis is divided into three regions, viz. the *rostrum*, the *haustellum* and the *labella*.

The rostrum is composed of the following parts: the rostrum membrane (*r.m.*), the maxillary palps (*p.*), the stipites (*st.*), the anterior part of the common salivary duct (*c.s.d.*) with the salivary valve (*s.v.*), the hyoid (*hy.*) and the fulcrum (*ful.*). The last-named structure belongs morphologically to the head, and is formed by the fusion of the tormae (*t.*), the paratormae (*par.*) and the pharynx (*ph.*). All the sclerotised parts of the rostrum, except the palps and the tormae, lie inside the head capsule. To the anterior part of the rostrum membrane and the hyoid is attached the second region of the proboscis, or the haustellum (*hu.*). This region includes the labrum-epipharynx (*lep.*) the hypopharynx (*h.*), the labial gutter (*l.g.*) and the theca (*th.*). The two last-named parts belong morphologically to the labium. The labella (*lab.*) are the distal parts of the proboscis. Ventrally they are fused together and have the pre-stomal teeth in their anterior part. By the membranous joint they are attached to the furca (*fur.*) which articulates with the theca. Morphologically the labella belong to the labium, and represent the greatly modified labial palps.

The rostrum.

(Figs. V and VI.)

The rostrum membrane (*r.m.*) consists of two layers: the outer layer is very thin and slightly sclerotised; it bears minute, curved spines and is continuous with the primary cuticula. The inner layer is very thick, exhibits a fibrous structure and is stained a grey-blue colour by acid haemalum; it is continuous with the secondary cuticula of the sclerotised parts of the head. The attachment of the rostrum membrane to the head capsule has already been mentioned

in connection with the description of the head. It is attached to the mouth-parts in the following manner: the frontal part of the rostrum membrane, which arises from the anterior border of the fronto-clypeus and the genae, extends ventrally surrounding the tormae and the base of the maxillary palps. Below the palps it is attached to the posterior border of the labrum-epipharynx and is also connected with the proximal part of the stipites (Fig. VIII). Between each stipes (*st.*) and the dorsal border of the theca (*th.*) it is continuous anteriorly with the membranous part of the haustellum. The lateral and the posterior parts of the rostrum membrane, which arise respectively from the ventral border of the genae and from the postgenae, are attached along the

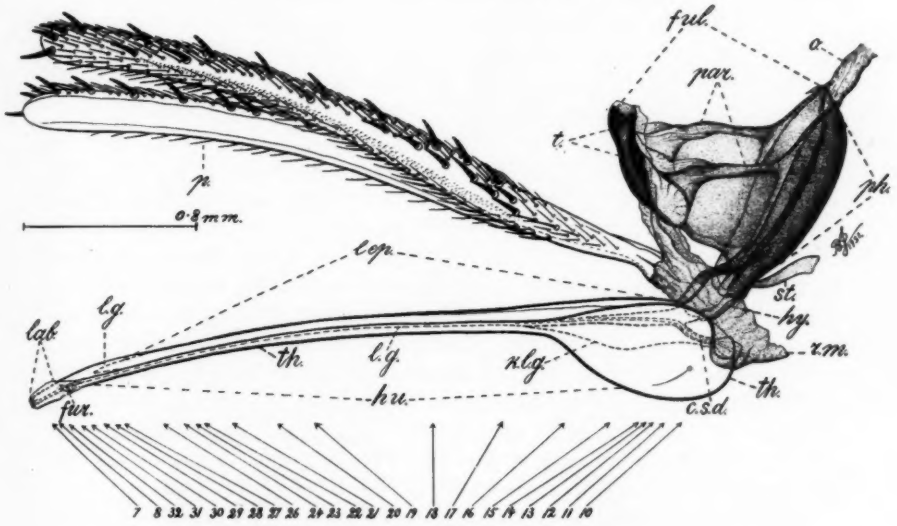

Fig. V. Proboscis of *Glossina palpalis* Rob.-Desv. The numbered arrows indicate the points through which the transverse sections of the haustellum (*hu.*) and the labella (*lab.*) bearing the corresponding numbers in Plates XIX–XXII were cut.

posterior border of the bulbous part of the theca. Immediately behind the theca, the membrane is gathered into the folds, which extend antero-dorsally along the inner margin of the genae.

The maxillary palps (*p.*) of *Glossina* each consist of a single segment, as in all the other Diptera Cyclorrapha. The palps are long, narrow and slightly curved downwards. Their outer surface is convex, strongly sclerotised and darkly pigmented; it bears very stout, black setae which are separated by more or less regular intervals on the dorsal margin. Between these setae and along the dorsal and the ventral margin there are many very much weaker ones. All the setae are pointed forwards, except the strongest one at the anterior end, which is directed slightly dorsally and inwards (Fig. V). Each

seta represents the trichoid sensilla; it has a big trichogenous cell, at the side of which lies a much smaller, oblong sense cell. By one end this sense cell is connected with a branch of the palpal nerve, while the other end is produced into a long process, the sense rod. The sense rod passes through the trichogenous cell and ends at the membranous base of the sensilla. Trichoid sensillae of this type were also described by Sihler (1924) in various insects.

The rest of the outer surface is beset with very small, slightly curved spines (Fig. 9, Pl.). The inner surface of the palps is concave and membranous, it is devoid of setae. The base of the palps is flat, its ventral part gives off a short process which projects inside the head and serves for the insertion of the muscle. The palps are attached close together to the anterior part of the rostrum membrane not far from the posterior border of the labrum-epipharynx. In the resting position the palps are applied to each other as in the Hippoboscidae, their concave inner sides forming a cavity in which the narrow part of the haustellum and the labella are concealed when the proboscis is at rest.

The stipites (*st.*) were called the apodemes by many authors. Patton and Evans (1929) homologised them with the tormae on account of their connection with the labrum-epipharynx. However, as regards the homology of the stipites, I agree with Peterson (1916), who followed the modification of these parts of the rostrum in all the families of Cyclorrhapha. He says of the Calyptratae: "The free so-called apodeme is unquestionably derived from the ental ingrowth of the stipes." In many Athericera, Calyptratae and Acalyptratae, which have been also studied by me, the proximal end of the stipites is attached to the galea. This is another proof that they are not the tormae. In *Musca*, *Calliphora* and *Sarcophaga* the galea is very rudimentary, while in the Hippoboscidae Jobling (1926) and in *Glossina*, it is indistinct, being apparently incorporated with the proximal end of the stipes.

Each stipes of *Glossina* is a long, slightly curved and sclerotised rod, which lies inside the head capsule (Figs. V and VIII). Its proximal end is movably attached to the posterior process of the labrum-epipharynx (*pos.pr.*), where it is also connected with the anterior part of the rostrum membrane. The distal end of the stipes is spatulated and concave; it serves for the insertion of the muscles of the rostrum and lies at the side of the fulcrum.

The fulcrum (*ful.*). It has already been pointed out in the general description of the proboscis that this structure is composed of two tormae, which are connected with the pharynx by the secondary structures, or the paratormae. The tormae (*t.*) of Peterson (1916), or the clypeus of many other authors, lie in the antero-ventral part of the head capsule, between the genae and below the fronto-clypeus, to which they are attached by the rostrum membrane (Figs. I and II). The tormae represent more or less triangular plates which are connected with each other by a narrow semi-membranous strip (Fig. VI A). The lateral part of the tormae, bent dorsally, forms thick, darkly pigmented folds, irregular in outline. Behind these folds the tormae

are fused with the paratormae (*par.*). The paratormae are square-shaped plates of which the dorsal and the ventral edges are thickened, while the middle part is very thin. Posteriorly they are attached to the anterior borders of the pharynx, which is formed by an anterior and a posterior plate. The posterior plate, or the posterior wall of the pharynx, is deeply concave and

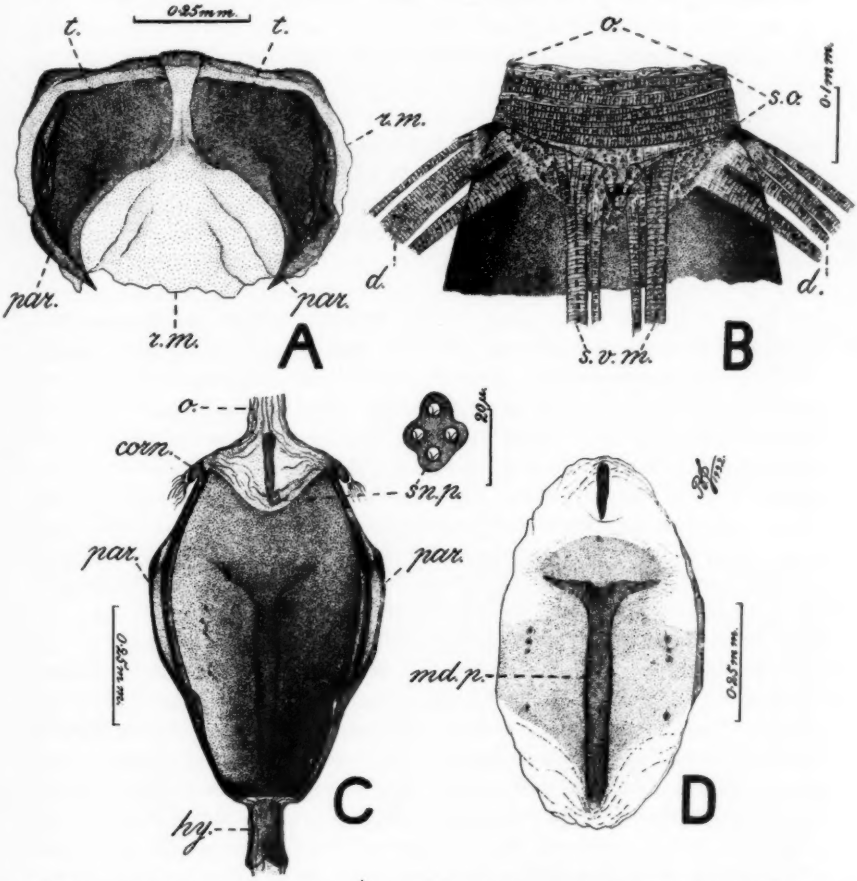

Fig. VI. *Glossina palpalis* Rob.-Desv. A, tormae; B, posterior part of pharynx, showing sphincter of oesophagus (*s.o.*), salivary valve muscles (*s.v.m.*) and depressor muscles of pharynx (*d.*); C, frontal view of pharynx and hyoid (*hy.*); D, anterior plate of pharynx.

strongly sclerotised (Fig. VI C). It is gutter-shaped when viewed laterally; its borders, to which are attached the paratormae, are curved inwards. These borders end by small processes, or cornua (*corn.*), between which the posterior wall is arched. The anterior plate, or the anterior wall of the pharynx, is membranous, and is attached to the lateral borders of the posterior wall

(Fig. VI D). In the middle of the anterior wall there is a sclerotised T-shaped plate, the median plate of the pharynx (*md.p.*), which serves for the insertion of the dilator muscles of the pharynx. On each side of the median plate, a little nearer to the lateral border, there are three or four very minute sensillae projecting into the lumen of the pharynx. These sensillae are very common on the anterior wall of the pharynx of many Cyclorrhapha.

According to Kraepelin (1883) they serve to hold back any solid particles which may be drawn into the alimentary canal. But according to Frey (1921), who examined the pharynx of many Acalyptrata, they represent true sense organs. My own examination of the pharynx of many Calyptrata showed that the number of these sensillae is not sufficient for them to act as a sieve. Immediately behind the arched edge of the posterior wall there is a very small, sclerotised plate, the sensory plate of the pharynx (*sn.p.*). It is square shaped and has three or four very short basio-conical sensillae, which project into the posterior part of the lumen of the pharynx. Each of these sensillae has a trichogenous cell through which passes a comparatively thick sense rod from the sense cell. This rod ends at the base of the sensillae and is connected through the sense cell with a branch of the pharyngeal nerve (Fig. VI B).

Between the cornua the walls of the pharynx are continuous with those of the oesophagus (*o.*). Immediately above the pharynx, the oesophagus forms a loop and then passes backwards through the canal of the cephalic ganglion towards the mid-gut. The wall of the oesophagus is formed of the intima, which is lined externally by a layer of epithelial cells. Over these lie the striated circular muscles, which are surrounded externally by the peritoneal membrane. There are no longitudinal muscles in the wall of the oesophagus, as described by Stuhlmann (1907). The circular muscles very much resemble the cardiac muscles owing to their very extensive branching. Near the pharynx these muscles form two moderately thick bands, an anterior and a posterior one. These bands are the sphincters of the oesophagus (*s.o.*); each of them extends across the oesophagus, being inserted into its lateral parts above the cornua. Besides the sphincters there are a few very small bands of muscles in the posterior part of the anterior wall of the pharynx, round and above a very small and narrow sclerotised plate. This plate is shown immediately above the median plate (*md.p.*) (Fig. VI C and D). The anterior part of the pharynx is much narrower than the posterior and is connected by a membranous joint with the hyoid.

The *hyoid* of Lowne (1890–2) (*hy.*), or the propharynx of Patton and Evans (1929), is the secondary structure which in many Cyclorrhapha connects the pharynx with the epipharynx and the hypopharynx. In *Lyperosia*, *Stomoxys* and *Haematobia*, the hyoid is a trachea-like tube, while in *Scatophaga*, *Musca*, *Calliphora* and *Sarcophaga*, it is a small sclerite, the ventral wall of which is strongly sclerotised, whereas the dorsal wall is membranous. The hyoid is very much better developed in the Hippoboscidae than in any other Cyclorrhapha, and is development its undoubtedly connected with the great

retractibility of the proboscis in this family, Jobling (1926). The hyoid of *Glossina* resembles more or less that of *Musca* and *Calliphora* (Figs. V and VI). It is a tubular sclerite of which the ventral wall is sclerotised and darkly pigmented, while the dorsal wall is membranous (fig. 11, Pl.). The lumen of the hyoid is continuous posteriorly with that of the pharynx, to which it is attached by the membranous joints. Anteriorly it is connected with the posterior part of the epipharynx and the hypopharynx; here its lumen is continuous with the food canal of the haustellum (Fig. VII).

The pumping action of the pharynx depends upon the contraction and the relaxation of the dilator muscles of the pharynx and the sphincters of the oesophagus. The *dilator muscles of the pharynx of Glossina* (*di.ph.*) are homologous to the same muscles of the Muscidae. These muscles are very strong; they arise from the tormae and occupy the whole space between the paratormae, being inserted into the median plate and the membrane of the anterior wall of the pharynx (Fig. VII; fig. 10, Pl.).

The contraction of the dilators of the pharynx and the sphincters of the oesophagus appears simultaneously. The former pair of muscles draw the anterior wall of the pharynx from the posterior, thus distending the lumen of the pharynx. Since the oesophagus is closed by its sphincters, the food will flow into the pharynx. During the relaxation of the dilators, the anterior wall invaginates into the lumen of the pharynx and forces the food into the oesophagus. Inside the oesophagus the food is moved towards the crop by peristalsis, which is brought about by the ring muscles.

THE MUSCLES OF THE ROSTRUM AND THE HEAD.

(Fig. VII; figs. 10 and 12, Pl.)

It has already been shown that the antero-dorsal part of the head capsule is occupied by the inflated ptilinum. The cephalic ganglion, which is supported by the body of the tentorium, lies in the posterior part of the head, a little dorsally of the occipital foramen. It consists of the closely united supra-oesophageal (*sp.g.*) and the sub-oesophageal (*sb.g.*) ganglions. From the dorsal part of the supra-oesophageal ganglion arises the ocellar nerve (*oc.n.*), and from its lateral parts, which represent the optic lobes, the optic nerves take their origin. These nerves together with the compound eyes occupy nearly the whole lateral parts of the head capsule. The antennal nerves (*an.n.*) arise from the olfactory lobes, which are situated in the antero-lateral parts of the supra-oesophageal ganglion. Not far from the olfactory lobes, each antennal nerve gives off a long branch which innervates the dorsal parts of the head. From the antero-ventral parts of the supra-oesophageal ganglion, or trito-cerebral lobes arise short nerves which form small ganglions (*g.*) behind the pharynx. Each of these ganglions give off about four branches, of which the ventral one apparently represents the labral nerve, while the antero-dorsal branch encircles the oesophagus and unites with the same branch of the other

ganglion, forming a small thickening, or the frontal ganglion. Posteriorly the frontal ganglion gives off the recurrent nerve which passes along the dorsal wall of the oesophagus towards the proventriculus. The sub-oesophageal ganglion gives origin to the labial nerves (*lb.n.*).

The space of the dorsal parts of the head capsule above the cephalic ganglion and round the antennal nerves and the cone of the compound eyes, is occupied by the big air sacs (*ai.s.*). Between the latter there are groups of multinuclear fat cells, which together with small air sacs and tracheae, are also found round the proboscis and between its sclerotised parts and the muscles.

The musculature of the head is very well developed and all the muscles are homologous with those of the Muscidae and the Hippoboscidae. In *Glossina*, however, the action of some muscles is quite different from that in the above-mentioned families, in consequence of the difference in the structure of the head capsule and the position of the sclerotised part of the rostrum. In *Glossina* as in *Stomoxys* (Hansen, 1903) and in the Hippoboscidae (Jobling, 1926), the protraction of the proboscis depends entirely upon the action of its muscles, but not upon the respiratory system, as described by Kraepelin (1883) and Hewitt (1914) in *Musca*.

Besides the muscles of the antennae and the pharyngeal muscles, which have already been described, the following muscles are found in *Glossina*.

The *depressors of the fulcrum* (*d.ful.*) correspond to m^7 of Hansen (1903) and the protractors of the proboscis and fulcrum of Stuhlmann (1907). These muscles are very strong and are homologous to the same muscles of the Muscidae and the Hippoboscidae, but in *Musca* they act as the retractors of the fulcrum. Each of these muscles arises from the tentorial thickening of the ventral part of the gena and is inserted into the posterior cornu of the pharynx (Fig. VI B).

The *elevators of the stipites* were not described by Hansen or Stuhlmann. They are homologous to the same muscles of the Hippoboscidae (Jobling, 1926) and to the accessory flexors of the haustellum of *Musca* (Hewitt, 1914). Each of these muscles is very short and broad, it arises from the middle of the thickened ventral border of the paratorma and is inserted into the distal end of the stipes. This muscle is shown by dotted lines in Fig. VII.

The *depressors of the stipites* (*d.st.*, fig. 10, Pl.) correspond to m^3 of Hansen and the stretcher of the proboscis of Stuhlmann. These muscles are homologous to the extensors of the haustellum in *Musca*, and the retractors of the stipites in the Hippoboscidae. Each of these muscles is of the same size as the elevator of the stipes, it arises from the ventral border of the paratorma close to the pharynx and is inserted into the distal end of the stipes near the elevator. It is shown by dotted lines in Fig. VII.

The *elevators of the haustellum* (*e.hu.*) corresponds to m^1 of Hansen and the elevators of the haustellum of Stuhlmann. These muscles are homologous to the flexors of the labrum-epipharynx of *Musca*, and the protractors of the haustellum of the Hippoboscidae. Each of these muscles is narrow, it arises

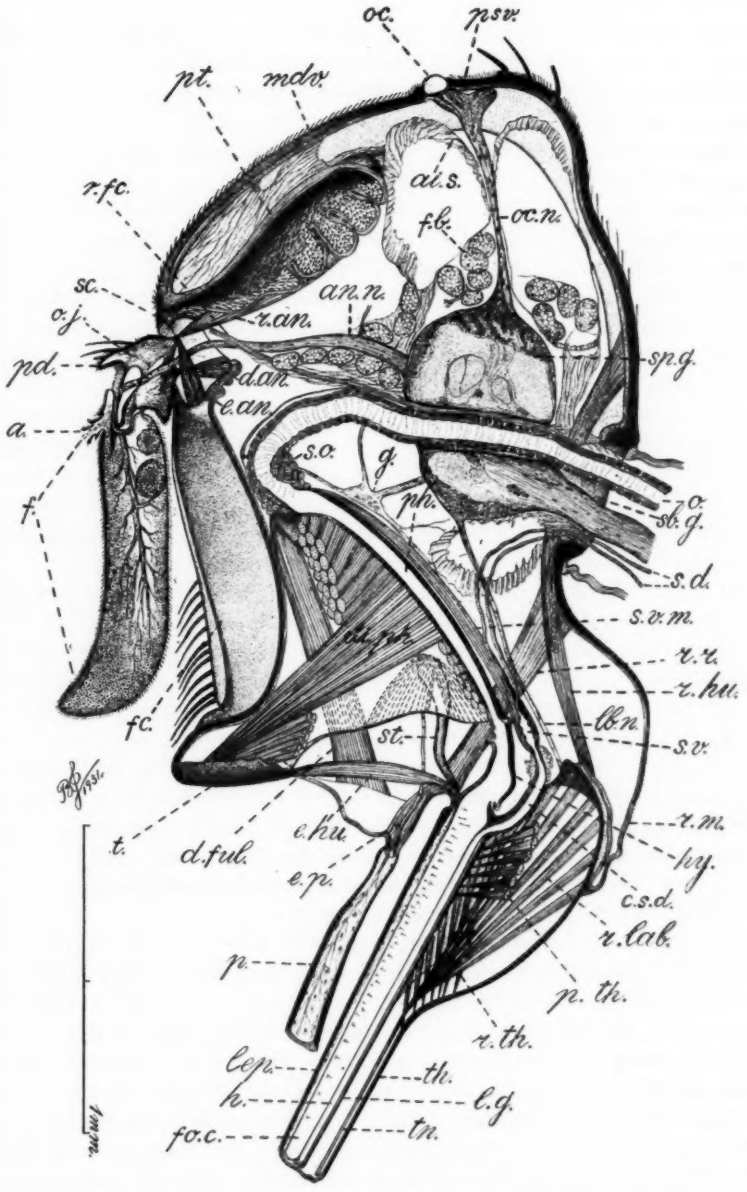

Fig. VII. Right half of head of *Glossina palpalis* Rob.-Desv., showing internal structure and muscles of proboscis.

from the posterior part of the torma and is inserted into the posterior process of the labrum-epipharynx.

The *retractors of the rostrum* (*r.r.*) correspond to m^2 of Hansen and the retractors of the proboscis of Stuhlmann. These muscles are homologous to the same muscles of *Musca* and the Hippoboscidae. Each of these muscles is very strong; it arises near the thickened edge of the occipital foramen, ventrally to the attachment of the body of the tentorium and is inserted by its tendons (*tn.*) into the proximal part of the stipes.

The *retractors of the haustellum* (*r.hu.*) correspond to m^4 of Hansen and the sinker-retractor of the proboscis of Stuhlmann. These muscles are homologous to the same muscles of *Musca* and the Hippoboscidae. Each of these muscles is very long; it arises partly from the thickened edge of the occipital foramen, a little above the origin of the retractor of the proboscis and partly from the occipital apodeme. It is inserted into the posterior edge of the bulbous part of the theca (Fig. VIII and fig. 10, Pl.).

The examination of more than a hundred spirit specimens of *Glossina* showed that the haustellum may occupy the following positions with regard to the head capsule: it may be horizontal and lie concealed between the palps; this position is acquired by the haustellum when the proboscis is at rest. On the other hand it may be depressed and directed downwards. This last position of the haustellum has also been described by many authors who had seen the fly in the act of feeding. Besides the depression and the elevation, which appear to be the main movements of the haustellum, it can be protracted and retracted. Since it has also been found in many specimens that the bulbous part of the depressed haustellum may either be exposed and lie completely outside the head capsule, or be partly withdrawn and concealed by the folds of the rostrum membrane.

These movements of the haustellum are brought about by the above-described muscles of the rostrum, which act as a parallelogram of forces. The position of the sclerotised parts of the rostrum and the attachment of the muscles shows that the depressors and the elevators of the stipites contract first. In so doing they push the stipites against the labrum-epipharynx. Since the posterior part of the labrum-epipharynx is fused with the other parts of the haustellum, the latter becomes depressed. With these muscles co-operate the retractors of the haustellum. All these muscles also serve to turn the haustellum towards the sides. The contraction of the depressors of the fulcrum lowers it and, as the hyoid connects the fulcrum with the haustellum, the latter is pushed out by the action of the depressors. During the retraction and the elevation of the haustellum its retractors and the retractors of the rostrum contract first. These two pairs of muscles withdraw the haustellum into the ventral part of the head, pushing the hyoid and the fulcrum upwards. When the posterior part of the haustellum is partly withdrawn, the contraction of its elevators brings it to the horizontal position under the ventral part of the head capsule.

The elevators of the palps (*e.p.*) were described by Stuhlmann under the same name. These muscles are very small; each of them arises from the posterior process of the labrum-epipharynx, close to the elevators of the haustellum and is inserted into the proximal end of the palp.

The *retractors of the fronto-clypeus* (*r.fc.*), according to Stuhlmann, maintain the bend of the anterior part of the oesophagus, but I could not find any connection of this muscle with the oesophagus. It is an unpaired muscle and is very thin and long. It arises from the dorsal edge of the occipital foramen, whence it passes through the canal of the cephalic ganglion over the dorsal wall of the oesophagus towards the fronto-clypeus where it is attached above the antennae, close to the ventral edge of the ptilinal suture. The structure of this muscle shows that it is non-functional in the adult insect. It retracts the fronto-clypeus and the ptilinum inside the head after the hatching of the fly.

There are two other very small muscles in the head, the function of which is obscure. Each of these muscles arises from a dorsal process of the body of the tentorium and is inserted into the edge of one of the ocular apodemes (Fig. I B, *ms.*).

THE HAUSTELLUM.

(Figs. VIII and IX; Pls. XX, XXI and XXII.)

The structure of the haustellum of *Glossina* much more closely resembles that of the Hippoboscidae than of the blood-sucking Muscidae. The mouth-parts forming this region of the proboscis, viz. the labium, the labrum-epipharynx and the hypopharynx are very narrow, greatly elongated and lie in close contact with each other. They have undergone modification to enable them to penetrate easily into the puncture of the skin of the host which has been made by the labella. It is seen in Fig. V that the posterior part of the haustellum is bulbous, while the rest represents a slightly curved, more or less rounded rod. The shortest diameter of the haustellum is about 60μ, while its length including the labella is 3·2 mm. in *G. palpalis* Rob.-Desv., 3·25 mm. in *G. morsitans* Westw., 4·2 mm. in *G. brevipalpis* Newst., and according to Stuhlmann (1905) 3·8 mm. in *G. fusca* Walk. As in all the other Diptera, the largest portion of the haustellum is formed by the labium. The latter is composed of two sclerotised parts: a ventral, the theca (*th.*), and a dorsal, the labial gutter (*l.g.*). These parts of the labium are connected together by the labial membrane.

The posterior, or the bulbous part of the theca is cordiform, it is darkly pigmented and bears generally two moderately long setae arising from its ventral surface (Fig. VIII). The posterior edge of the theca has a concave structure (*Y-s.s.*) which is Y-shaped in transverse sections (fig. 10, Pl.). Through the middle of this structure passes the common salivary duct to the hypopharynx. On each side of the concave structure the posterior edge of the theca is strengthened by a thickening and curves sharply dorsally. Into the semicircular curvatures of these parts, between the edge and the thickening,

are inserted the retractor muscles of the haustellum, and to the thickening is attached the rostrum membrane (*r.m.*). The lateral walls of the bulbous part of the theca bend dorsally and then inwards (fig. 11, Pl.; figs. 15 and 16, Pl.). In the posterior part of the bulb, the dorsal edges of the theca are connected by the rostrum membrane with the posterior processes of the labrum-epipharynx (*pos.pr.*); but anteriorly to these processes the rostrum membrane merges into the labial membrane (*lb.m.*), which connects the dorsal edges of the theca with the lateral parts of the labial gutter. In the frontal part of the bulb the theca becomes suddenly very narrow; here from its internal surface arise two processes (*pr.th.*), which project dorsally and serve for the insertion of the muscles of the labium (fig. 17, Pl.). From the frontal part of the bulb the theca extends along the narrow part of the haustellum as a thick-walled gutter (figs. 18–26, Pl.). The anterior end of the theca is very narrow and is fused with a horseshoe-shaped sclerite, the furca (*fur.*), which is homologous to the same structure of the muscid proboscis (Fig. X A and C). Not far from its anterior end the lateral parts of the theca extend half-way dorsally, forming triangular pieces. These are thickened dorsally and are attached to the ventral parts of the labial gutter. Besides the setae arising from the ventral part of the wall of the bulb there are two parallel rows of very minute sensillae along the narrow part of the theca (Fig. X E). These sensillae are situated at the bottom of small pits and are connected through the pore canal (*pr.c.*) with the sense cells, which in their turn are connected with branches of the labial nerves (fig. 19, Pl.). Stephens and Newstead (1906) misunderstood these structures; it is quite obvious from their description that as the result of an optical effect, they mistook the pore canal and the pit for the scale.

The dorsal part of the labium, or the labial gutter, is also very strongly sclerotised; it is this part and the theca which make the haustellum very rigid. The posterior end of the labial gutter is fused with the hypopharynx ventrally and with the lateral parts of the labrum-epipharynx dorsally (fig. 12, Pl.; figs. 13 and 14, Pl.); but in the middle of the bulb they become separated from each other. In the bulbous part of the theca, the labial gutter gives off three processes which serve for the attachment of the muscles of the labium (figs. 15–17, Pl.). Of these processes two arise from the lateral part of the labial gutter and are directed postero-laterally (*pr.l.g.*), while the third process, or the keel of the labial gutter (*k.l.g.*), arises from the ventral part. It is very broad and is nearly as long as the bulbous part of the gutter. The structure of the labial gutter in the narrow part of the haustellum and the labella is better understood in the transverse sections (figs. 16 and 17, Pl.). It is seen that the lateral parts of the labial gutter extend dorsally on each side of the labrum-epipharynx (*lep.*), until they completely enclose the latter and overlap each other in the anterior part of the haustellum (figs. 18–26, Pl.). These parts are semi-membranous and bear slightly sclerotised, parallel ridges, the internal ridges (*in.rid.*). The latter arise from the

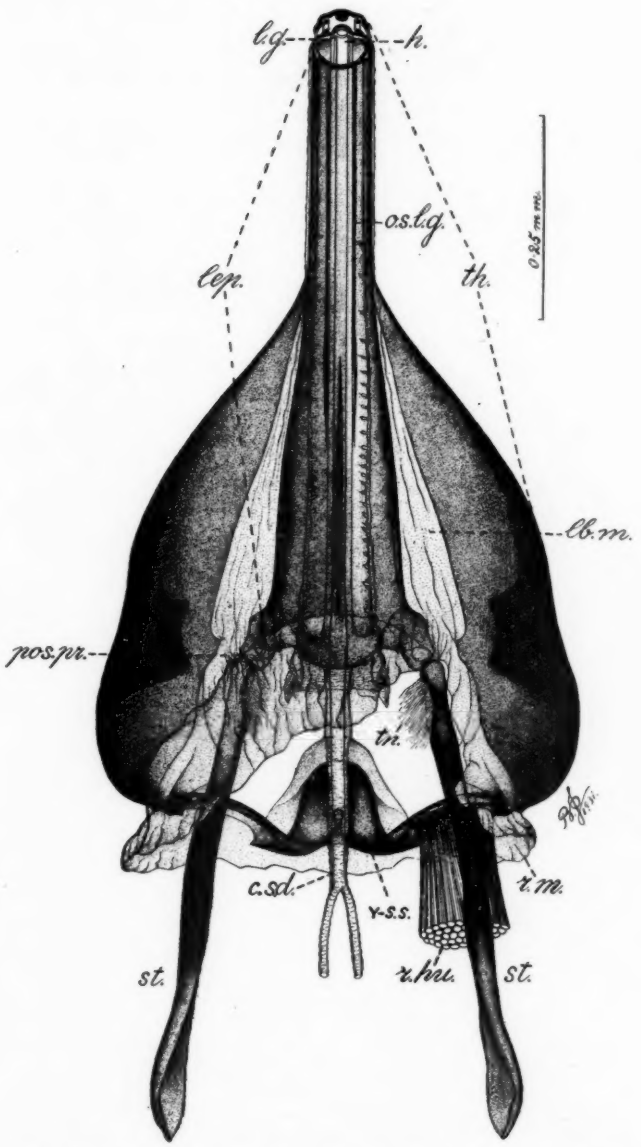

Fig. VIII. Bulbous part of haustellum of *Glossina palpalis* Rob.-Desv., showing position of labrum-epipharynx (*lep.*) hypopharynx (*h.*), common salivary duct (*c.s.d.*) and attachment of stipites (*st.*), rostrum membrane (*r.m.*) and retractor muscle of haustellum (*r.hu.*).

inner surface and interlock with the teeth of the labrum-epipharynx. By several authors these ridges were described as teeth, which they resemble only in the transverse sections (Fig. X D). The outer surface of these parts of the gutter is only slightly sclerotised in the middle of the haustellum, while towards the anterior end the sclerotisation becomes interrupted by a membranous network, producing on the outer surface a polygonal pattern resembling a crazy pavement (Fig. X A and D). The ventral part of the labial gutter is strongly sclerotised; it is depressed along the middle, forming a rounded groove in which lies the hypopharynx (*h.*). The wall of this groove projects ventrally into the cavity of the labium and together with the thick lateral parts of the labial gutter forms small grooves in which lie the labial nerves (*lb.n.*). In the anterior part of the haustellum and in the labella the structure of the labial gutter becomes modified. This modification is impossible to follow out in the total preparation of the proboscis, because the different parts obscure each other. It is in this part of the proboscis that some previous workers described the "movable sclerites" which actually do not exist.

Before proceeding to the description of this part of the labial gutter, it is necessary to point out that in Fig. X A, the arrows with the numbers indicate the points through which the transverse sections indicated by the corresponding numbers in Pl. XXII were cut.

The section cut through point 22 shows that the thick lateral walls of the labial gutter are fused with the lateral parts of the theca, and on each side of the wall of the groove in which lies the hypopharynx appear knob-like thickenings. In the next section cut at point 23, which is only about 25μ from point 22, the structure of the gutter is distinctly different. Here it is again connected with the theca by the labial membrane, and its lateral walls are very much thinner but more sclerotised. From the wall of the groove in which lies the hypopharynx, two triangular processes project laterally. The following five sections show that these processes extend along this part of the labial gutter as far as the posterior end of the labella (fig. 29, Pl.). They serve to strengthen this part of the gutter and apparently act like springs, bringing the lateral walls of the labial gutter towards each other after the feeding of the fly, since the walls of the labial gutter are diverted from each other during feeding (fig. 4, Pl.). In the following two sections, cut at points 24 and 26, the structure is practically the same. Anteriorly to point 26, the internal ridges (*in.rid.*) and the external polygonal sclerotisations gradually disappear from the overlapping part of the lateral walls of the labial gutter. It is in this part of the labium that the theca (*th.*) becomes narrow anteriorly and is fused with the furca (figs. 27 and 28, Pl.), which is connected by the labial membrane with the labella. In the ventral part of the labial membrane, near the posterior edge of the labella there are two sclerotised sense plates (*sn.p.*). Each plate bears three minute sensillae which are connected through the pore canal with the sense cells (figs. 25 and 29, Pl.). There are beside two, or more, often three minute sensillae on each side of the labial membrane

between the narrow anterior part of the theca and the labial gutter (Fig. X A). In the middle of the labella the sclerotised lateral walls of the labial gutter become gradually separated from each other by a thick membrane (fig. 31, Pl.). A little further on this membrane extends along the internal surfaces of the lateral wall, while their sclerotised external surfaces become divided into three curved plates (*pl.l.g.*). Anteriorly these plates are continuous with the anterior part of the labial membrane which forms the inner wall of the labella (fig. 32, Pl.).

The *hypopharynx* (*h.*) is a very long and exceedingly slender, double-walled tube, the proximal end of which is fused with the basal part of the labial gutter (Fig. IX C; Pls. XXI and XXII). The external wall of the hypopharynx is formed by the evagination of the floor of the mouth; it is moderately thick and sclerotised in its proximal part, but in the middle and the anterior parts it is as thin as the internal wall. The internal wall represents the elongated anterior part of the common salivary duct, which runs through the entire length of the hypopharynx and opens at the tip of the latter ventrally (Fig. IX D; fig. 31, Pl.). The lumen of the salivary duct of the hypopharynx has a diameter of 15μ in the posterior part, whereas in the middle and the anterior part it is about 8·5μ.

The position of this mouth-part in the haustellum is as follows: from the Y-shaped structure of the posterior wall of the theca, the common salivary duct (*c.s.d.*) passes through the posterior part of the cavity of the labium and penetrates into the labial gutter dorsally (Fig .VII; figs. 10, 11 and 12, Pl.). This part of the labial gutter is apparently formed by the fused posterior end of the hypopharynx. The suture of the line of the fusion makes its appearance when the hypopharynx becomes distinct as a separate organ overlying the gutter (fig. 13, Pl.). In the narrow part of the haustellum it is enclosed in the groove formed by the ventral wall of the labial gutter (figs. 18–29, Pl.). But in the posterior part of the labella where this groove gradually disappears, the hypopharynx lies in the food canal, between the lateral walls of the labial gutter (figs. 30 and 31, Pl.). Its tip extends as far as the middle part of the labella, but during the eversion of the latter the tip of the hypopharynx is considerably nearer to their anterior edge, and it is here that the saliva mixes with the blood during the feeding of the fly.

The labrum-epipharynx and the food canal (*fo.c.*) *of the haustellum and the labella.* The labrum-epipharynx (*lep.*) is spear-shaped when examined in total preparation (Fig. IX A). As in all the other Diptera, it is formed by the fusion of the labrum (*l.*) with the epipharynx (*ep.*). The posterior part of the labrum-epipharynx is strongly sclerotised, but towards the anterior end it becomes gradually more or less membranous. It occupies the dorsal position in the haustellum, forming the dorsal wall of the food canal and is connected with the other parts of the proboscis in the following manner: in the posterior part of the haustellum the dorsal membranous wall of the hyoid (*hy.*) is continuous anteriorly with the epipharynx, while its sclerotised ventral wall is attached

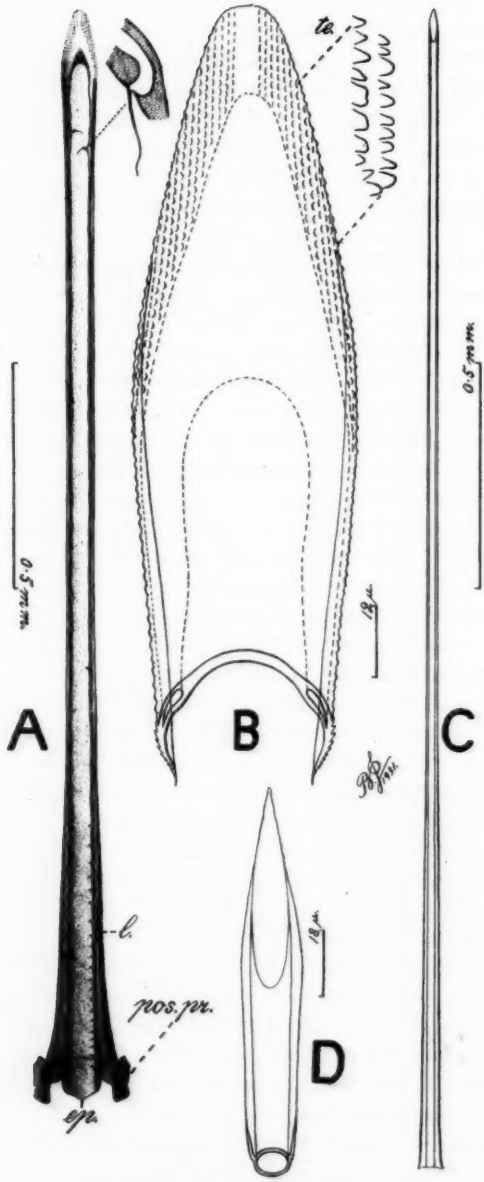

Fig. IX. *Glossina palpalis* Rob.-Desv. A, labrum-epipharynx; B, distal end of same; C, hypopharynx; D, distal end of same.

by the membranous joint to the labial gutter above the common salivary duct (Fig. VII). Here the lumen of the hyoid merges into the lumen of the food canal of the haustellum which is formed by the epipharynx (*ep.*) dorsally and the labial gutter ventrally (figs. 11 and 12, Pl.). It is seen in the last section that laterally to the epipharynx and the labial gutter lie the posterior processes of the labrum (*pos.pr.*), to which are attached by thick filaments the stipites (*st.*). Anteriorly to this point the lateral parts of the labial gutter extend dorsally and become fused with the posterior processes of the labrum (fig. 13, Pl.). At this point the antero-ventral part of the cavity of the head becomes divided into two parts: a dorsal, or the cavity of the labrum-epipharynx and a ventral, or the cavity of the labium. The cavity of the labrum-epipharynx is formed by the epipharynx ventrally and the posterior part of the rostrum membrane (*r.m.*) and the labrum dorsally. This cavity is invested by the hypodermis, and in its lateral parts lie the labral nerves (*l.n.*) which give off branches to the sensillae of the epipharynx. A little anterior to the point just mentioned the dorsal part of the epipharynx fuses with the dorsal part of the labrum, dividing their cavity into two (fig. 14, Pl.). Here the ventral parts of the labrum-epipharynx become gradually separated from the labial gutter, so that in the middle of the bulbous part of the haustellum the labrum-epipharynx lies free, over the labial gutter (fig. 15, Pl.). In the anterior part of the bulb and in the narrow part of the haustellum the food canal is almost entirely formed by the labrum-epipharynx, since here its lateral walls extend toward each other and their ventral edges lie on the dorsal surface of the hypopharynx (figs. 16 and 17, Pl.; figs. 18 and 19, Pl.). In this part of the haustellum the labrum-epipharynx is enclosed in the labial gutter and its sclerotised teeth interlock with the internal ridges of the latter. The teeth (*te.*) make their appearance on the lateral surfaces of the labrum-epipharynx in the anterior part of the bulb. From here they run in parallel rows, extending as far as its tip, where they become less sclerotised and irregular in shape and size (Fig. IX B). In the anterior part of the haustellum the labrum-epipharynx narrows, its tip lies between points 26 and 27 in the middle of the food canal which is formed here by the labial gutter (Fig. X A; fig. 26, Pl.).

The external surface of this mouth-part, that is not enclosed in the labial gutter, is smooth and bears no cuticular appendages. The stalked hairs described by Stephens and Newstead (1906) on this surface are, in fact, the sensillae arising from the epipharynx. The appearance of the stalks is purely an optical effect produced by the pore canal in the wall of the epipharynx when the labrum-epipharynx is examined in the total preparation (Figs. VIII and IX A). These sensillae project into the food canal of the haustellum and are connected through the pore canals with the labral nerves (figs. 15 and 16, Pl.). There are two of these sensillae near the tip of the labrum-epipharynx. Each of them is very long and arises from the dorso-lateral part of the epipharynx, being directed postero-laterally. Similar sensillae but much

shorter are present in the posterior part of the epipharynx. Here they are arranged in a double row along the latero-dorsal parts and are directed ventrally inside the food canal.

The labella.

(Fig. X; Pls. XVII and XIX.)

The labella form the most anterior region of the proboscis. They have been greatly modified in consequence of the adaptation of *Glossina* to the blood-sucking habit. This habit is probably of earlier origin in these flies than in any other of the blood-sucking Muscidae, since in *Glossina* the structure of the labella has undergone much greater modification from the non-blood-sucking type than in any other blood-sucking species of the same family.

In general appearance the labella of *Glossina* resembles very much those of the Hippoboscidae previously described by me (Jobling, 1926).

The labella of *Glossina* are slightly elongated and are fused together by their ventral parts forming a thick-walled, sclerotised gutter (figs. 30–32, Pl.). However, this fusion does not extend to the most anterior end of the labella, where their ventral edges are separated from each other (fig. 6, Pl.). The anterior end of each labellum is rounded. Here the surface of its outer wall is ridged. These ridges (*rid.*) extend from the anterior edge backwards, they are irregular in shape and become very short towards the dorsal edge of the labellum. The structure of these ridges is better seen in the transverse sections (fig. 6, Pl.). From the lateral wall of the labellum arise seven small (*sm.s.*) and four flagelliform (*fl.s.*) sensillae. They have been described by Stephens and Newstead as spines. These sensillae are attached to a very thin rounded membrane which arises from the edge of the pore canal. Through these canals they are connected with the nervous system of the labellum. The position of these sensillae varies a little in the different specimens of the labellum; this partly depends upon the position of the mounted specimens on the slides. Generally there are three small sensillae close to the anterior edge of the labellum. Behind these there is one small one in the ventral part and three flagelliform in the middle. All these sensillae arise from the broad ridges. Posterior to these there are one small and one flagelliform sensilla and two small ones more or less close together in the middle, but nearer to the posterior end of the labellum. All the sensillae are directed posteriorly, except the three small ones at the anterior edge.

The anterior part of the ventral wall of the labella, which is formed by their fusion, is membranous and slightly concave. It bears a group of small ventral denticles (*v.dt.*) which are directed posteriorly. These are better seen in the everted labella (figs. 1 and 2, Pl. XVIII). Behind these denticles the ventral wall becomes sclerotised. The posterior half of this wall is of dark brown colour and has a wrinkled surface. The wrinkles are much more distinct in the middle of the dark area, while towards the middle and the posterior edge of the labella they gradually disappear (figs. 1 and 2, Pl.). The postero-lateral part

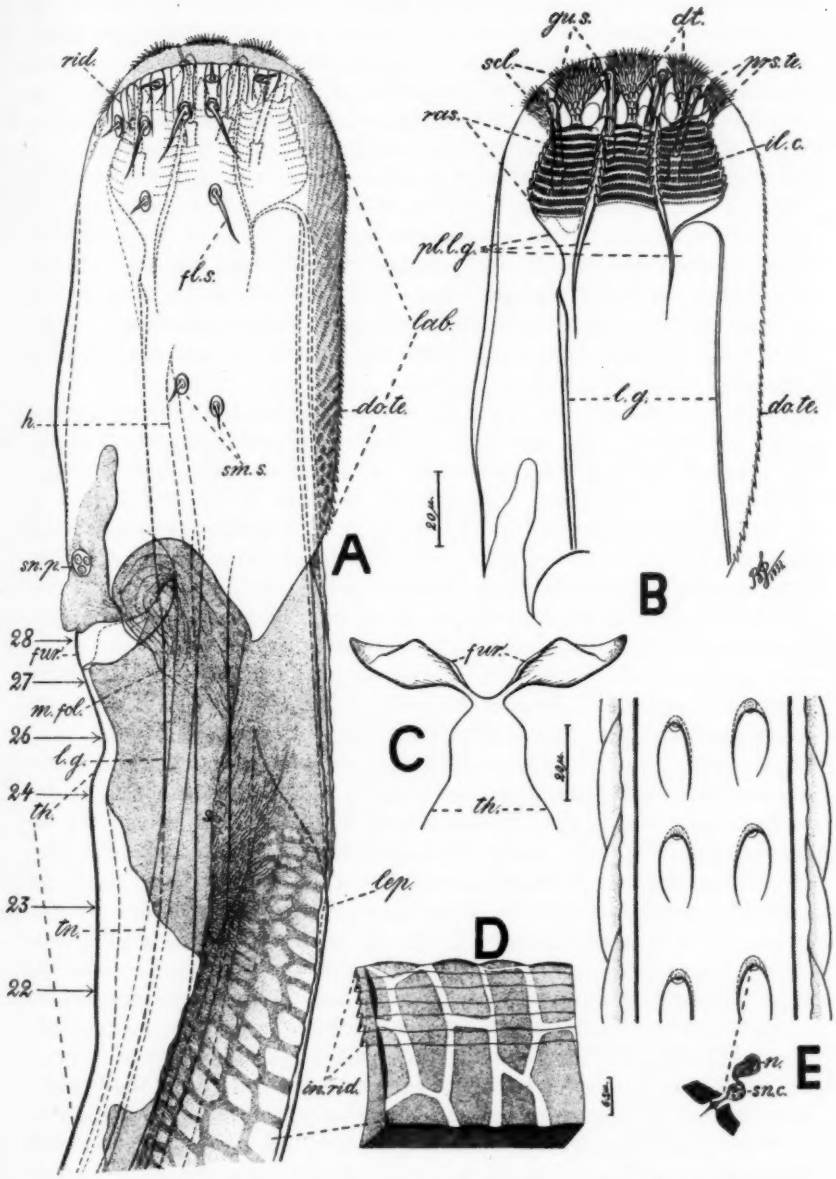

Fig. X. *Glossina palpalis* Rob.-Desv. A, lateral view of labella (*lab.*) and anterior parts of haustellum; B, inner wall of labellum showing armature and gustatory sensillae (*gu.s.*); C, anterior end of theca (*th.*) and furca (*fur.*); D, dorsal part of labial gutter; E, internal view of narrow part of theca, showing pore canal and sensilla.

of each labellum ends in two triangular pieces: one of which is in front of and the other above the furca (Fig. X A). Here the parts of the labial membrane, which extends from the anterior border of the furca and the labial gutter, are attached to the posterior border of the labella. From this border the membrane extends along the dorsal borders of the labella connecting these with the lateral walls of the labial gutter (figs. 29–32, Pl.). The surface of this membrane bears numerous dorsal teeth (*do.te.*). It is seen in the everted labella (figs. 1 and 2, Pl.) that these teeth are of different size and are arranged in more or less regular rows; the largest teeth occupy the most dorsal position in the rows, whereas ventrally they become smaller in each row. They are also much smaller in the anterior than in the posterior rows. In the anterior part of the labella the labial membrane extends along their anterior edges. From there it bends inwards forming the inner wall of the labella and is attached to the anterior edge of the labial gutter.

The most anterior part of this membrane forms the sides of an oval opening, the prestomum, into the food canal. Behind the prestomum, on the inner wall of the labella, are located the parts of the boring apparatus of the proboscis.

In order to understand better the complicated structure of these parts and their arrangement, we must refer to the structure of the anterior part of the labial gutter. It has already been shown that in the anterior part of the labella the wall of the labial gutter becomes divided into six plates (*pl.l.g.*): two dorsal which overlap each other by their free ends, two broad lateral and two narrow ventral ones (fig. 32, Pl.). Immediately in front of these plates, on the membranous inner wall of each labellum, there are present toothed structures. These have been described by Hansen (1903) as "rasps." These rasps (*ras.*) are strongly convex and are formed by parallel sclerotised ridges which bear a row of very sharp teeth. There are three rasps in each labellum. According to their position they may be divided into the dorsal, the median and the ventral rasps (Fig. X B; figs. 7 and 8, Pl.). The teeth of the posterior ridge of each rasp are very small and inconspicuous. It has been found that there are twelve ridges in the dorsal, ten in the median and eleven in the ventral rasps. In the transverse sections and in the total preparations of the labella the rasps appear to be continuous with the corresponding plates of the labial gutter. Actually, however, they are separated from these plates by membranous joints which are only visible in horizontal transverse sections of the labella (fig. 5, Pl.). The membranous inner wall of the labella is invaginated between the rasps, forming deep grooves. These extend a little anteriorly to the rasps, while posteriorly they are continuous between the plates of the labial gutter. These grooves, together with the joints just described, make the inner wall of the labella more flexible and allow it to be stretched out during its eversion. At the anterior end of each rasp there are four strongly sclerotized prestomal teeth (*prs.te.*). Two of these teeth are small and cone-shaped; they are attached laterally to the most anterior ridge of the rasp. In front of these there are the

other two teeth, which are very much larger, but unequal in size; generally one of them is nearly twice as long as the other. At the dorsal and the ventral rasps the largest prestomal tooth is the internal one, while in front of the median rasp the largest is the dorsal tooth. As regards the shape of the large prestomal teeth, it depends very much upon the position of the inner wall of the labella under the microscope (figs. 1 and 2, Pl.). They all appear to be very broad at their base and have a slightly curved distal part which narrows to a sharp point.

Between the largest prestomal teeth and in the dorsal and the ventral parts of the inner wall of the labellum there are five groups of very small denticles (*dt.*), which resemble very much the ventral denticles of the outer wall of the labella. These denticles are arranged in more or less regular rows between the teeth. In the posterior row there are only two denticles, while in the most anterior one there may be as many as four or five. Towards the anterior edge of the inner walls of the labella each set of these denticles merges gradually into long, flexible scales (*scl.*). These are arranged in a fan-shaped manner and have been named by Stephens and Newstead the "fans." According to Cragg (1913) the scales of the fans are homologous to the petiolated blades of *Stomoxys* and also to the pseudo-tracheal rings of the labella of *Musca*.

Besides the armature, the inner wall of each labellum has two small and four very large gustatory sensillae (*gu.s.*). The small sensillae arise laterally to the median group of scales, in front of the large prestomal teeth. Owing to their small size, they are not very conspicuous. On the other hand, the large sensillae are very distinct; they arise from the invaginated part of the inner wall, between the rasps. Stephens and Newstead have described the small sensillae as the "spine-bearing rods," and the large ones as the "jointed rods." But, in fact, all these sensillae have the same structure and only differ in size. In the total preparations of the labella, each sensilla appears to be composed of two sclerotised parts: a distal long and narrow and a proximal short and broad part. Actually, however, the proximal part is the internal structure which represents the intralabial canaliculus (*il.c.*). The canaliculus arises from the membranous inner wall of the labella and projects posteriorly into the labial cavity (figs. 3 and 5, Pl.). To the proximal edge of the canaliculus the narrow base of the sensilla is attached by a very thin and flexible membrane. Each sensilla represents a slightly curved rod of which the distal dilated end is rounded. Through the sensilla passes the pore canal which bends over and narrows abruptly inside the dilated tip. It is seen in the transverse sections of the sensilla that this canal ends blindly (fig. 3, Pl.). The pore canal of the sensilla is continuous with that of the canaliculus, through which the living part of the sensilla is connected with the nervous system of the labella (fig. 5, Pl.).

The internal structure and the muscles of the labium.

(Fig. VII; Pls. XIX–XXI.)

In the preceding two sections the sclerotised parts of the labium have been described. An account will now be given of the internal structure and the muscles.

The cavity of the labium, which lies between the labial gutter and the theca and the labella, is very much reduced through the adaptation of this mouth-part to the blood-sucking habit. In the posterior part of the labium the cavity is continuous with that of the head capsule. The wall of the labial cavity, as well as that of the head, is invested by the hypodermis which consists of the continuous layer of very flat cells (*hp.c.*). These cells are especially very flat and inconspicuous in the narrow part of the labial cavity. They are better seen when dislodged from the integument and also in tangential sections.

The respiratory system of the labium consists of the air sacs and the tracheae which are arranged in the following manner: In the ventral part of the head capsule laterally to the pharynx and the hyoid, there are present two large air sacs (*ai.s.*). These sacs extend into the bulbous part of the labial cavity (figs. 10 and 11, Pl.). In the posterior part of the bulb each sac lies between the muscles, but in the anterior part it occupies the ventral position, below the muscle (figs. 15 and 16, Pl.). From the dorso-anterior part of these air sacs arise two labial tracheae (*tr.*). These give off many branches to the muscles in the bulbous part of the labium. The main branches of these tracheae lie in contact with the labial nerves, and together with the latter, they pass through the narrow part of the labial cavity into the labella.

The nervous system of the labium consists of two labial nerves (*lb.n.*) arising from the sub-oesophageal ganglion. These nerves pass behind the pharynx inside the head capsule. They enter the labial cavity laterally to the hyoid and the common salivary duct (fig. 11, Pl.). In the bulbous part of the labium these nerves give off several branches to the muscles and the sensillae. In the narrow part of the labial cavity the labial nerves lie in the grooves which have already been described. Here from the labial nerves arise many very fine and short branches ventrally. These innervate the sensillae of the theca. In the posterior part of the labella each labial nerve becomes dilated, forming a sort of ganglion from which arise several branches to the sensillae of the labellum. The dilated part and the branches of the nerve have many pyriform or spindle-shaped nerve cells (fig. 5, Pl.; figs. 30–32, Pl.). Each of these cells possesses a very large nucleus of which the chromatin granules are stained a dark blue colour by haemalum. The labial cavity of the labella is almost entirely occupied by the nervous system, and, contrary to the belief of some students, there is no other tissue, except the hypodermis.

The fat-body cells are present in the bulbous part of the labial cavity only.

These cells occur in small groups, here and there between the muscles, chiefly in the most posterior part of the cavity.

The muscles of the labium occupy the bulbous part of the labial cavity only. The number of sets of the muscles and their attachment are exactly the same as in the labium of the Hippoboscidae. Moreover, all these muscles are homologous to those of the blood-sucking and non-blood-sucking Muscidae.

The *retractors of the theca* (*r.th.*) correspond to the median bulb muscles of Stuhlmann (1907). These muscles are homologous to the dilators of the labium-hypopharynx in *Musca* (Hewitt, 1914) and to the transverse muscles of the haustellum in *Calliphora* (Lowne, 1890–92; Graham-Smith, 1930). In the Hippoboscidae these muscles were named by the writer (Jobling, 1926) the protractors of the labial gutter. It must be pointed out here that in this family and in *Glossina* it is the theca which can be moved forwards and backwards along the labial gutter on account of the flexibility of the wall of the bulb and the labial membrane, whereas the labial gutter is immovable in respect of the hyoid. Therefore, the name given to these muscles in this paper appears to be more suitable. These muscles arise from the posterior part of the labial gutter and its keel (*k.l.g.*) and are directed obliquely and anteriorly. They occupy the median position in the bulb. The short hyaline tendons of these muscles are inserted into the processes of the theca (*pr.th.*). The contraction of these muscles pulls the theca backwards.

The *protractors of the theca* (*p.th.*) are homologous to the retractors of the discal sclerites in *Musca* (Hewitt, 1914), to the retractors of the paraphysis in *Calliphora* (Graham-Smith, 1930), and to the retractors of the labial gutter in the Hippoboscidae (Jobling, 1926). In *Glossina*, as in the family just mentioned, these muscles arise from the upper postero-lateral parts of the dorsal half of the bulb and are inserted into the lateral processes of the labial gutter (*pr.l.g.*). The contraction of these muscles pushes the theca forwards.

The *retractors of the labella* (*r.lab.*) correspond to the fork muscles of the bulb of Stuhlmann (1907). These muscles are homologous to the retractors of the furca in *Musca* (Hewitt, 1914) and in *Calliphora* (Lowne, 1890–2; Graham-Smith, 1930) and to the same muscles in the Hippoboscidae (Jobling, 1926). These are the strongest and the most important muscles of the labium. They arise from the posterior and the postero-lateral parts of the bulb. Each of these muscles consists of two bands (figs. 11 and 12, Pl.). These bands are inserted into the strong tendon (*tn.*) which passes through the narrow part of the labial cavity to the labellum, where it is attached to the furca, and to the posterior edge of the outer wall of the labellum (fig. 5, Pl.; figs. 18–28, Pl.). The contraction of these muscles pulls the outer walls of the labella along the labial gutter towards the head, everting their inner walls and the armature.

The movement of the labella and the action of the armature.

(Fig. X; Pls. XVIII and XIX.)

The retraction of the outer walls and the eversion of the armature of the labella depend entirely upon the action of the muscles; while the protraction of these walls and the inversion of the armature is produced by the tension of the sclerotised anterior parts of the labial gutter and the theca. The mechanism by which this movement is brought about may be very easily understood by comparison of the position of the different parts in the resting and in the everted labella.

The examination of the resting labella (Fig. X A and B) shows that the armature is withdrawn and lies concealed inside the labella, except the most anterior rows of the scales (*scl.*), which project anteriorly. These scales close the entrance into the food canal. It is also seen that the narrow anterior part of the theca (*th.*) is bent outwards at point 26, the furca is declined anteriorly, and there are no folds in the posterior parts of the labial membrane which connect the posterior edge of the outer walls of the labella with the theca.

In the everted labella there are present very great changes in the disposition of the above-mentioned parts (figs. 1 and 2, Pl.). These changes are brought about in the following way: when the retractor muscles of the labella contract, their long tendons (*tn.*) pull the outer walls of the labella and the furca backwards, bending the anterior part of the theca inwards and forming numerous folds in the labial membrane. The retracting outer walls of the labella evert the inner walls and the armature. During the eversion of the inner walls the resulting tensions divert the lateral parts of the labial gutter from each other, so that the labella become gutter-shaped and the food canal opened dorsally (fig. 4, Pl.).

When the retractor muscles of the labella relax, the anterior part of the theca and the furca resume their normal position. During this movement the furca pushes the outer walls of the labella forwards, inverting the inner walls and the armature. At the same time the lateral parts of the labial gutter are brought towards each other by their own tensions and by those of the outer walls of the labella. The food canal becomes closed dorsally and the labella resume their original form (figs. 6–8, Pl.). It has been found by measurement that the outer walls of the labella may be retracted backwards from 45 to 65μ.

During the retraction and protraction of the outer walls the inner walls become alternately everted and inverted. As the armature is attached to these walls its teeth perform protrusible divergent movements. The main cutting action is brought about by the prestomal teeth, while the rasps act like files. The dorsal teeth (*do.te.*) and the denticles apparently serve for the fixation of the labella in the puncture, whereas the main armature is not adapted for this purpose, because the inner walls, to which it is attached, become constricted in the completely everted labella (figs. 1 and 2, Pl.).

It has already been mentioned that the anterior part of the theca is fused with the labial gutter at point 22 (Fig. X A; fig. 22, Pl.). From this it results that during the retraction of the theca by the retractor muscles, the lateral pieces of its anterior part pull the labial gutter downwards, bending the anterior end of the haustellum ventrally just behind point 22. This condition of the haustellum has been found in all the resting proboscides. In the feeding flies the anterior part of the haustellum is straight and there is no bend at the point of fusion. This is brought about by the protractor muscles of the theca. These muscles push the theca forwards, so that its lateral pieces press against the labial gutter; thus the anterior part of the haustellum becomes straightened. The action of the retractor and the protractor muscles of the theca also produces tension in the sclerotised parts of the haustellum. This tension increases considerably the rigidity of the narrow part of this region of the proboscis.

The act of feeding of different species of the genus *Glossina* has been described by several workers. When the fly settles on the skin with the intention of feeding, it spreads its legs a little, lowers the haustellum into the vertical position and then introduces it into the skin. The movement of the armature of the labella is presumably very quick, since the haustellum is pushed into the skin very rapidly. The palps are sometimes slightly elevated during the feeding. Before the haustellum is to be withdrawn from the puncture, the palps sometimes move rapidly up and down. According to Lester and Lloyd (1928) the fly may push the proboscis (haustellum) into the skin as far as the bulb, but during the sucking of the blood only one-third of this part of the proboscis is inserted into the puncture.

THE SALIVARY GLANDS.

(Fig. XI.)

The first study of the salivary gland was made by Minchin (1905), who described the morphology and the position of the glands, but did not give the histology of these organs. Sander (1905) gave a very brief and incomplete account, while the description and the figures of Giles (1906) are not applicable to *Glossina*. Stuhlmann (1905 and 1907) studied the structure in greater detail; he described the histology of some parts and suggested an anticoagulant function for the glands.

The presence of an anticoagulin was demonstrated by York and Macfie (1924) and subsequently by Lester and Lloyd (1928). The latter authors showed that the anticoagulin is in the nature of an antithrombin. They have also demonstrated that the fly deprived of its salivary glands can still draw blood, but sooner or later large clots form in the food canal of the proboscis and in the crop, so that the fly can no longer feed and dies of starvation. Quite recently Wigglesworth (1929) has shown that the salivary glands of *Glossina* are free from digestive enzymes. The results of the experiments of

these authors show that the function of the secretion of the glands is to prevent the coagulation of blood in the anterior parts of the alimentary canal.

The salivary glands are two very long and very much coiled tubes. According to Newstead (1924) the length of the gland when straightened out may measure as much as 15 mm. The diameter of the glands is practically the same throughout their length, except the most anterior part where they merge into the ducts. It has been found that the convolution of one gland is quite different from that of the other in all the flies which have been dissected. Each gland occupies the dorso-lateral position in the abdomen, above the alimentary canal and below the dorsal or the pericardial diaphragm and the alary muscles, not above these muscles as stated by Minchin (1905). The posterior end of the glands extends as far as the sixth abdominal segment, while the coiled portion extends from the fifth to the first abdominal segment. In the anterior part of the abdomen the glands descend ventrally and merge more or less gradually into the ducts. From here the ducts pass laterally to the duct of the oesophageal diverticulum and in the neck laterally to the cephalo-thoracic nerve cord. In the posterior part of the head-capsule the salivary ducts become attenuated. They approach each other under the sub-oesophageal ganglion and then pass ventrally behind the pharynx (Fig. VII). Posteriorly to the hyoid the ducts unite forming the common salivary duct. The common salivary duct (*c.s.d.*) consists of two parts; a posterior which forms the salivary valve (*s.v.*) and an anterior which passes through the posterior part of the labial cavity from the Y-shaped structure of the theca into the hypopharynx.

An account will now be given of the histology of the ducts and the salivary glands. The most anterior part of the common salivary duct, which passes through the hypopharynx, is formed of the chitinous intima. In the posterior part of the theca, that is, between the hypopharynx and the concave Y-shaped structure of the theca (*Y-s.s.*), the intima of the wall of the common salivary duct is very thick (fig. 11, Pl.). Here its internal surface is sclerotised and has spiral-like taenidia, while externally it is membranous and is invested by the hypodermis which is formed of very flat cells. The intima stains blue with haemalum, or violet-blue when counter-stained with eosin. It is chitinous, since after a preliminary treatment with 60 per cent. caustic potash in an oil bath at 120° C. and washing with alcohols of decreasing strength and water, it becomes violet on addition of iodine. In the Y-shaped structure of the theca the wall of the duct becomes much thinner and is surrounded by a mass of epithelial cells (fig. 10, Pl.). The protoplasm of the narrow part of these cells exhibits a fibrillar structure. In the posterior part of the Y-shaped structure the epithelial cells form two small piriform structures (*pir.*) which project posteriorly inside the head capsule (Fig. XI A). According to Stuhlmann (1907) these structures represent the vestige of an organ which is functional in the larva. Histologically the piriform structure consists of a multinuclear mass of reticulated protoplasm and has a lumen in the middle

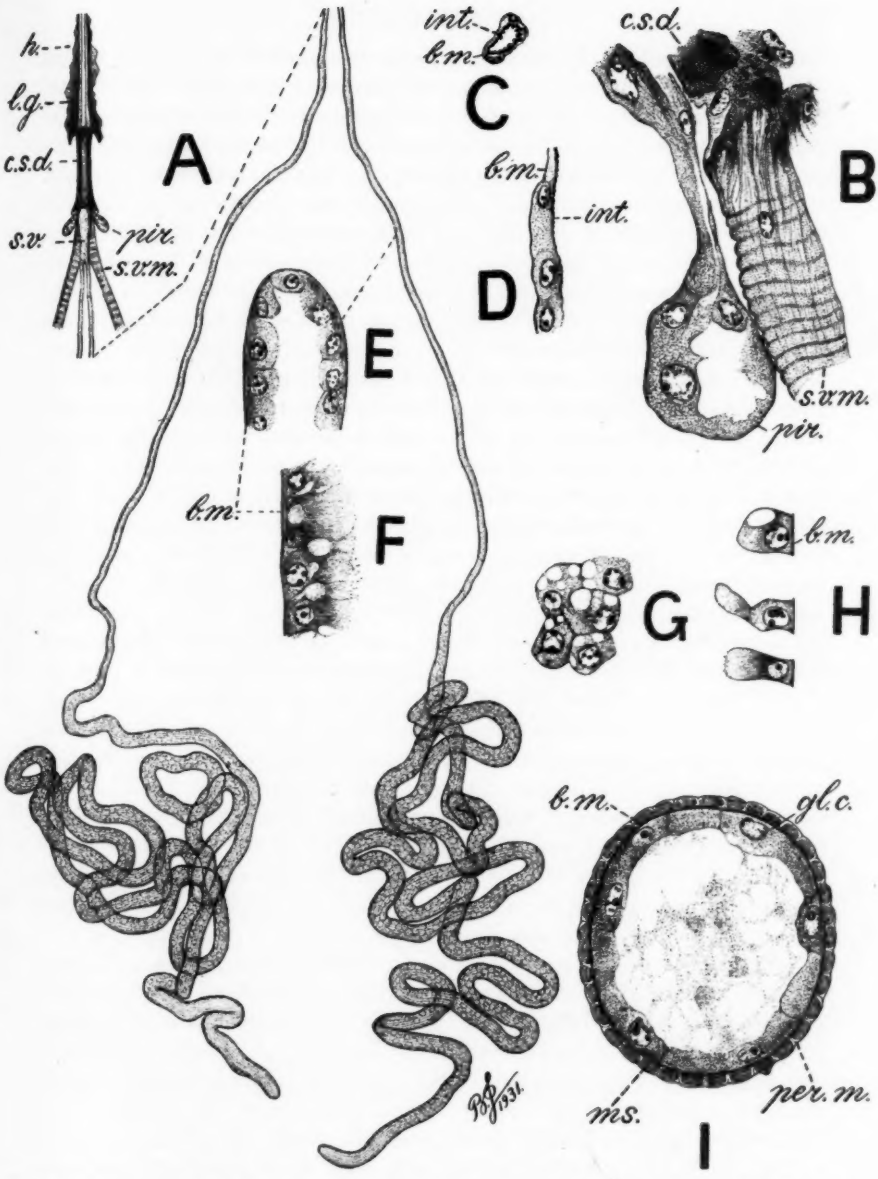

Fig. XI. *Glossina palpalis* Rob.-Desv. A, salivary glands, their ducts and hypopharynx (*h.*); B, piriform structure (*pir.*) and salivary valve muscle (*s.v.m.*); C, transverse section through salivary duct immediately behind salivary valve; D, longitudinal section of wall of salivary duct at most anterior part of thorax, showing modification of cells, intima (*int.*) and basement membrane (*b.m.*); E, oblique section of salivary duct of anterior part of thorax; F, gland cells with erupted internal parts; G, gland cell as seen in total preparation of salivary glands; H, gland cells with bulging internal parts; I, transverse section of convoluted portion of salivary glands. × 750, except A.

of its broad part (Fig. XI B). The structure resembles very much the acinus of a gland, but its lumen does not communicate with that of the salivary duct to which it is attached. Immediately behind the Y-shaped structure of the theca the posterior part of the common salivary duct forms the salivary valve (*s.v.*). The intima of the wall of the valve is very thin and is devoid of taenidia. Into the external surface of the valve are inserted the *salivary valve muscles* (*s.v.m.*) which arise from the middle part of the posterior plate of the pharynx, just below the oesophagus (Fig. VI B). The contraction of these muscles stretches out the membranous wall of the valve, widening the lumen. During the relaxation of these muscles the wall of the valve forms folds which project inwards and close the lumen.

At the posterior end of the valve the ducts of the glands become separated from each other. The wall of the ducts exhibits the following structure. Internally it is composed of the intima; this is bounded by the epithelial cells and these are followed by the basement membrane which is extremely thin (Fig. XI C). In the most anterior part of the thorax the structure of the wall of the ducts is gradually modified (Fig. XI D). Here the epithelial cells increase in size, the intima (*int.*) becomes very thin and indistinct, while the basement membrane (*b.m.*) gets thicker. Posterior to this point the epithelial cells of the salivary ducts become convex internally (Fig. XI E). The protoplasm of the internal part of these cells exhibits a reticular appearance and is stained a very light violet-blue colour by acid haemalum and eosine. The protoplasm of the outer part of these cells, between the nucleus and the basement membrane, is much denser and is stained a dark violet-blue colour. Each cell has a round or ovoid nucleus of which the chromatin granules stain dark blue, or almost black. These cells gradually merge into the gland cells. The transition takes place approximately along that portion of the salivary ducts which lies in the middle of the thorax. The main character of the gland cells is the presence of the vacuoles in their protoplasm. The non-secreting cells exhibit the same structure in all the preparations which have been studied, whereas the structure of the gland cells varies very much.

The gland cells (*gl.c.*) may be convex internally and have a reticulated protoplasm with a few vacuoles as shown in Fig. XI I, or they may have the structure shown in Fig. XI H. In these cells the reticulated protoplasm occupies the external part, between the nucleus and the basement membrane. The protoplasm of the other part of the cells, near the nucleus, has a fibrillar structure, but towards the bulging internal part it becomes reticulated and usually has vacuoles. These cells are generally associated with those shown in Fig. XI F. It is seen that the latter cells have practically the same structure, except their internal part, which is erupted. The reticulated contents of this part are generally continuous with those of the lumen of the gland and very often have many darkly stained granules. It is quite obvious that these cells show a later stage of modification than those shown in Fig. XI H. But without studying freshly dissected salivary glands, it is impossible to say

whether these modifications occur during secretion, or whether they represent an artifact produced by fixation.

The size of the cells is the same in all parts of the gland. The thickness of the convoluted portion is due to the wider lumen and the muscles (*ms.*). The cross-striated fibres of these muscles are as long as the convoluted portion of the glands. The muscles are arranged spirally next to the basement membrane and are bound by the peritoneal membrane (*per.m.*). Their fibres are separated from each other by a very thin membranous septa, which extends from the peritoneal membrane to the basement membrane and apparently represents a part of the sarcolema. Thus, the convoluted portion of the salivary glands consists of the following layers (Fig. XI I). Internally it is lined by the gland cells, the outer ends of which rest upon a second layer, the basement membrane. The latter is followed by the muscle fibres, which are invested by the outermost layer of the peritoneal membrane.

The muscles of the glands compensate for the absence of the salivary pump. The contraction of these muscles compresses the convoluted portion of the gland, squeezing the saliva through the ducts and the hypopharynx into the puncture.

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EXPLANATION OF PLATES XVIII TO XXII.

The points through which the transverse sections of the haustellum and the labella shown in the plates were cut are indicated in Fig. X (p. 477) by the arrows with the corresponding number.

PLATE XVIII.

Fig. 1. Lateral view of everted labella and anterior part of haustellum. ×650.
Fig. 2. Ventral view of same. ×650.

PLATE XIX.

Fig. 3. Gustatory sensilla. ×2000.
Fig. 4. Transverse section through most anterior part of everted labella. ×1000.
Fig. 5. Longitudinal horizontal section through middle part of labella. ×700.
Fig. 6. Transverse section through most anterior part of inverted labella. ×1000.
Fig. 7. Transverse section through anterior part of labella, showing position of rasps (*ras.*). ×500.
Fig. 8. Transverse section through labella posterior to section shown in fig. 7. ×500.

PLATE XX.

Fig. 9. Transverse section through palp. × 460.

Fig. 10. Transverse section through most antero-ventral part of head, showing pharynx (*ph.*) and most posterior part of theca (*th.*). × 200.

Fig. 11. Transverse section through most posterior part of bulb, showing position of hyoid (*hy.*), common salivary duct (*c.s.d.*) and muscles of labium. × 200.

Fig. 12. Transverse section through posterior part of bulb. Here epipharynx (*ep.*), labial gutter (*l.g.*) and hypopharynx fuse together. × 300.

PLATE XXI.

Fig. 13. Transverse section through bulbous part of haustellum, showing separation of hypopharynx (*h.*) from labial gutter (*l.g.*). Here labrum (*l.*) becomes fused with labial gutter. × 260.

Fig. 14. Transverse section through labial gutter and labrum-epipharynx (*lep.*), showing separation of these parts from each other. × 260.

Fig. 15. Transverse section through middle of bulbous part of haustellum, showing muscles of labium. × 200.

Fig. 16. Transverse section through anterior part of bulb, showing muscles of labium. × 200.

Fig. 17. Transverse section through most anterior part of bulb, showing insertion of muscles of labium and position of hypopharynx (*h.*) and labrum-epipharynx (*lep.*). × 300.

PLATE XXII.

Fig. 18. Transverse section through middle of narrow part of haustellum showing position of labrum-epipharynx (*lep.*), hypopharynx (*h.*) and food canal (*fo.c.*). × 500.

Fig. 19. Transverse section through middle of anterior half of haustellum. × 500.

Fig. 20. Transverse section through haustellum anterior to preceding section. × 500.

Fig. 21. Transverse section through anterior part of haustellum. × 500.

Fig. 22. Transverse section through anterior part of haustellum where theca becomes fused with labial gutter. × 500.

Fig. 23. Transverse section through haustellum slightly anterior to preceding section. × 500.

Fig. 24. Transverse section through anterior part of haustellum where theca (*th.*) becomes narrow. × 500.

Fig. 25. Section through sense plate (*sn.p.*) shown in fig. 29. × 750.

Fig. 26. Transverse section through anterior part of haustellum. Here labrum-epipharynx (*lep.*) ends and food canal (*fo.c.*) becomes formed by labial gutter (*l.g.*). × 500.

Fig. 27. Transverse section through most anterior part of haustellum, showing appearance of furca (*fur.*). × 500.

Fig. 28. Transverse section of haustellum anterior to preceding section, showing attachment of tendons (*tn.*) of retractor muscles of labella. × 500.

Fig. 29. Transverse section through most posterior part of labella. × 500.

Fig. 30. Transverse section through posterior part of labella. × 500.

Fig. 31. Transverse section through middle part of labella, showing membranous joint which connects lateral walls of labial gutter (*l.g.*). × 500.

Fig. 32. Transverse section through anterior part of labella showing plates of labial gutter (*pl.l.g.*). × 500.

KEY TO LETTERING OF PLATES XVIII TO XXII AND TEXT-FIGURES.

a. arista
ai.s. air sac
an. antenna
an.n. antennal nerve
bd.t. body of tentorium
b.m. basement membrane
bs.sn. basio-conical sensilla
cm.e. compound eye
col. collar
corn. cornua of pharynx
c.s.d. common salivary duct
d. depressor muscle of pharynx.
d.an. depressor of antenna
d.ful. depressor of fulcrum
di.ph. dilators of pharynx
do.te. dorsal teeth

d.st. depressor of stipes
dt. denticles
e.an. elevator of antenna
e.hu. elevator of haustellum
e.p. elevator of palp
ep. epipharynx
f. flagellum
fb. fat body
fc. fronto-clypeus
fl.s. flagelliform sensillae
fo.c. food canal
fr.s. frontal suture
fu. furrow
ful. fulcrum
fur. furca
g. ganglion
ge. gena
gl.c. gland cells
gu.s. gustatory sensilla
h. hypopharynx
hp.c. hypodermic cell
hu. haustellum
hy. hyoid
il.c. intralabial canaliculus
in.rid. interlocking ridges
int. intima
k.l.g. keel of labial gutter
l. labrum
lab. labella
lb.m. labial membrane
lb.n. labial nerve
lc. latero-cervical sclerite
lep. labrum-epipharynx
l.g. labial gutter
l.n. labral nerve
lv. laterovertex
m. membrane
mdv. mediovertex
md.p. median plate of pharynx
m.fol. membranous fold
ms. muscles
n. nerve
n.c. nerve cell
o. oesophagus
oc. ocellus
oc.ap. ocular apodeme
oc.br. ocular bristles
occ. occiput
occ.ap. occipital apodeme
occ.c. occipital condyle
occ.f. occipital foramen
oc.n. ocular nerve
oc.s. ocular sclerite
o.j. organ of Johnston
ol.p. olfactory pits
o.s.l.g. optical section of labial gutter
p. palp
par. paratormae
pd. pedicle
per.m. peritoneal membrane
ph. pharynx
pir. piriform structure
pl.l.g. plates of labial gutter
pos.pr. posterior process of labrum-epipharynx
pr.c. pore canal
pr.l.g. process of labial gutter
prs.te. prestomal teeth
pr.th. process of theca
psge. postgena
ps.oc.br. post-ocular bristles
psv. postvertex
ps.v.br. post-vertical bristles
pt. ptilinum
p.th. protractor of theca
pt.s. ptilinal suture
r.an. retractor of antenna
ras. rasp
r.fc. retractor of fronto-clypeus
r.hu. retractor of haustellum
rid. ridges
r.lab. retractor of labella
r.m. rostrum membrane
rot.an. rotator of antenna
r.r. retractor of rostrum
r.th. retractor of theca
s. sensilla
sb.g. sub-oesophageal ganglion
sc. scape
scl. scales
s.d. salivary duct
sm.s. small sensilla
sn.c. sense cell
sn.p. sensory plate
s.o. sphincter of oesophagus
sp. spine
sp.g. supra-oesophageal ganglion
st. stipes
s.v. salivary valve
s.v.m. salivary valve muscles
t. tormae
te. teeth
th. theca
tn. tendons
to.p. toothed process
tr. trachea
tr.c. trichogenous cell
tr.sn. trichoid sensilla
t.th. tentorial thickening
v.br. vertical bristles
v.dt. ventral denticles
w.lab. wall of labellum
Y-s.s. Y-shaped structure of theca

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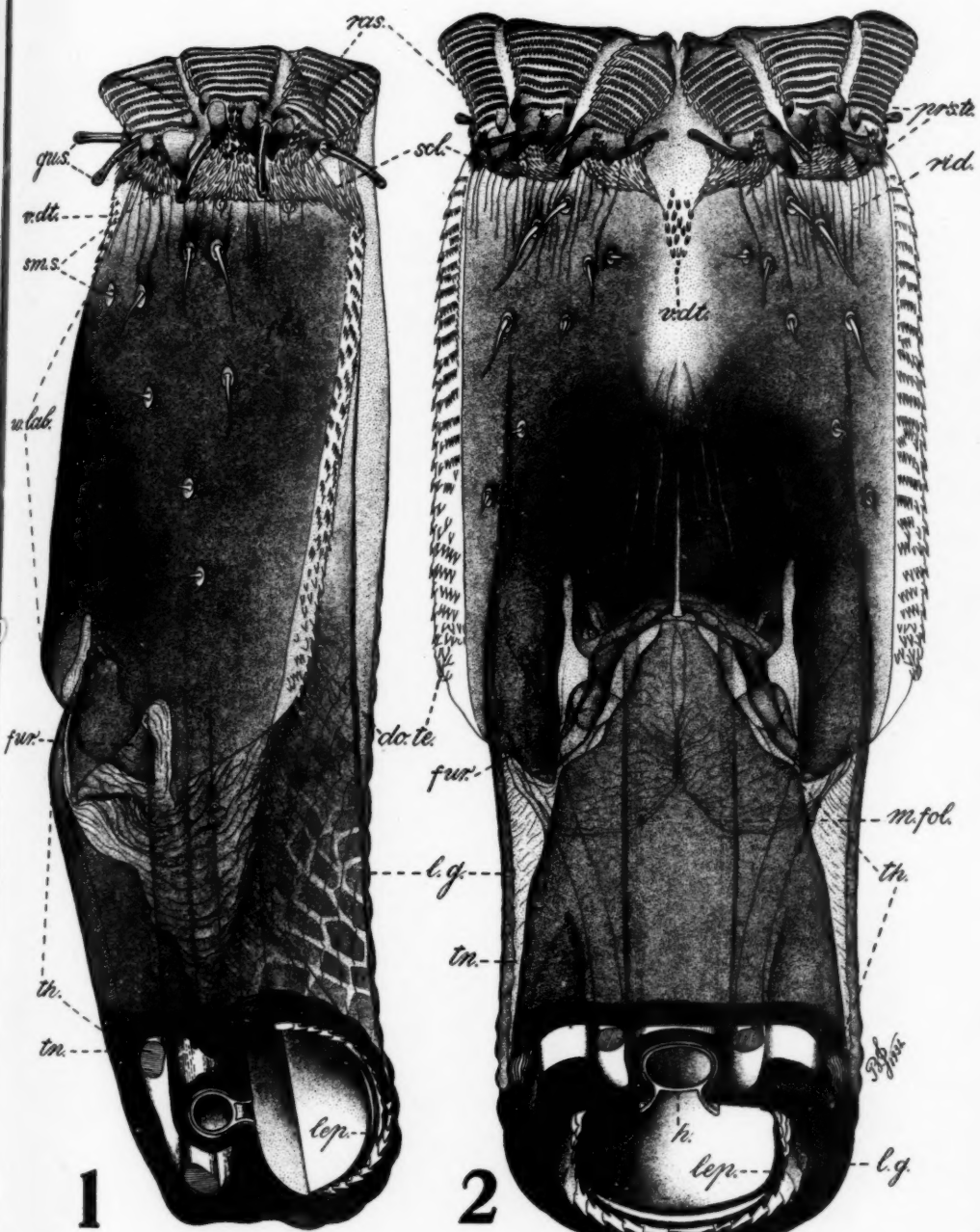
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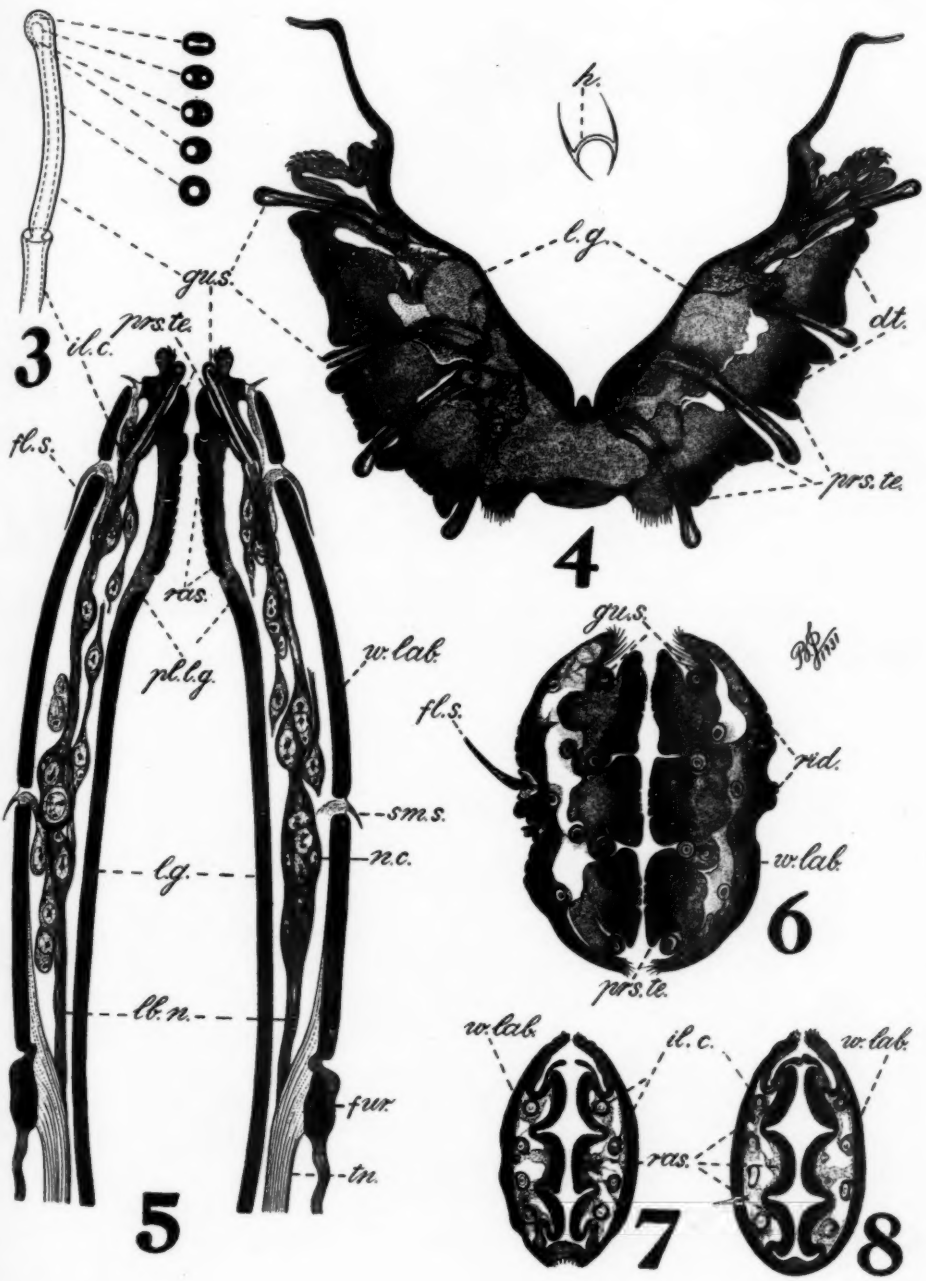
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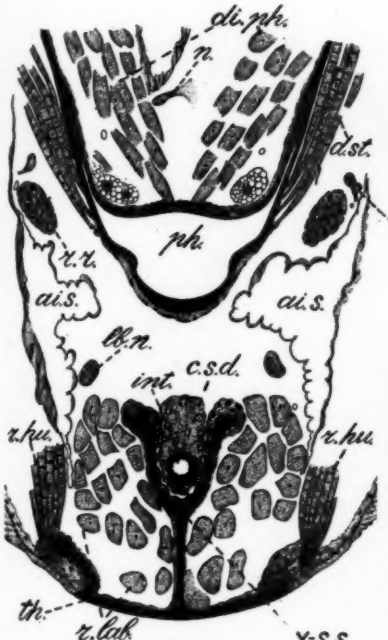

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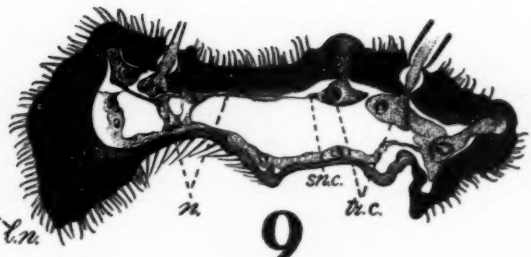

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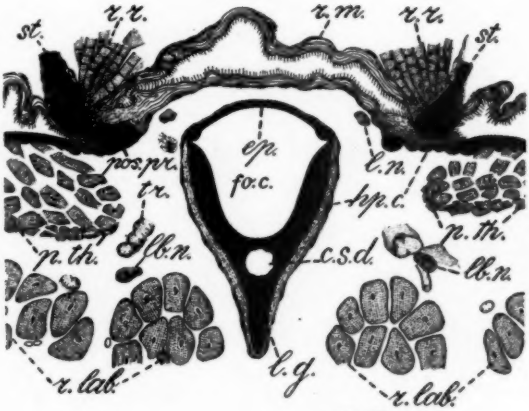

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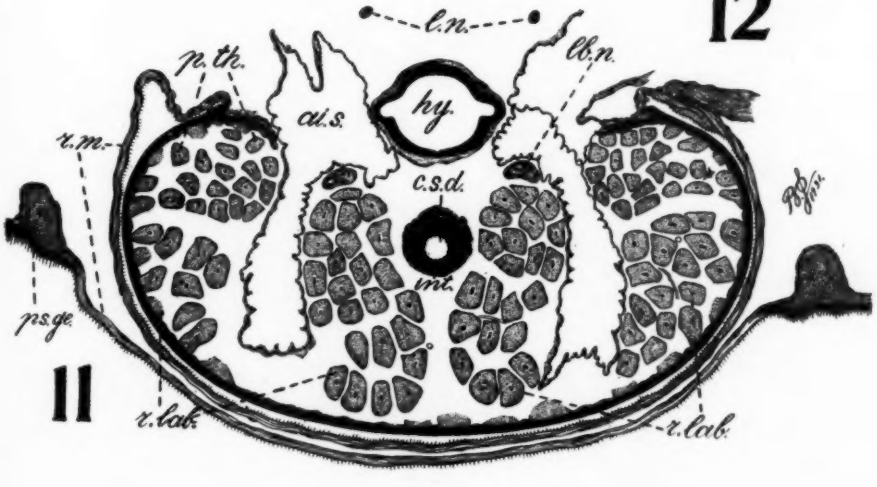

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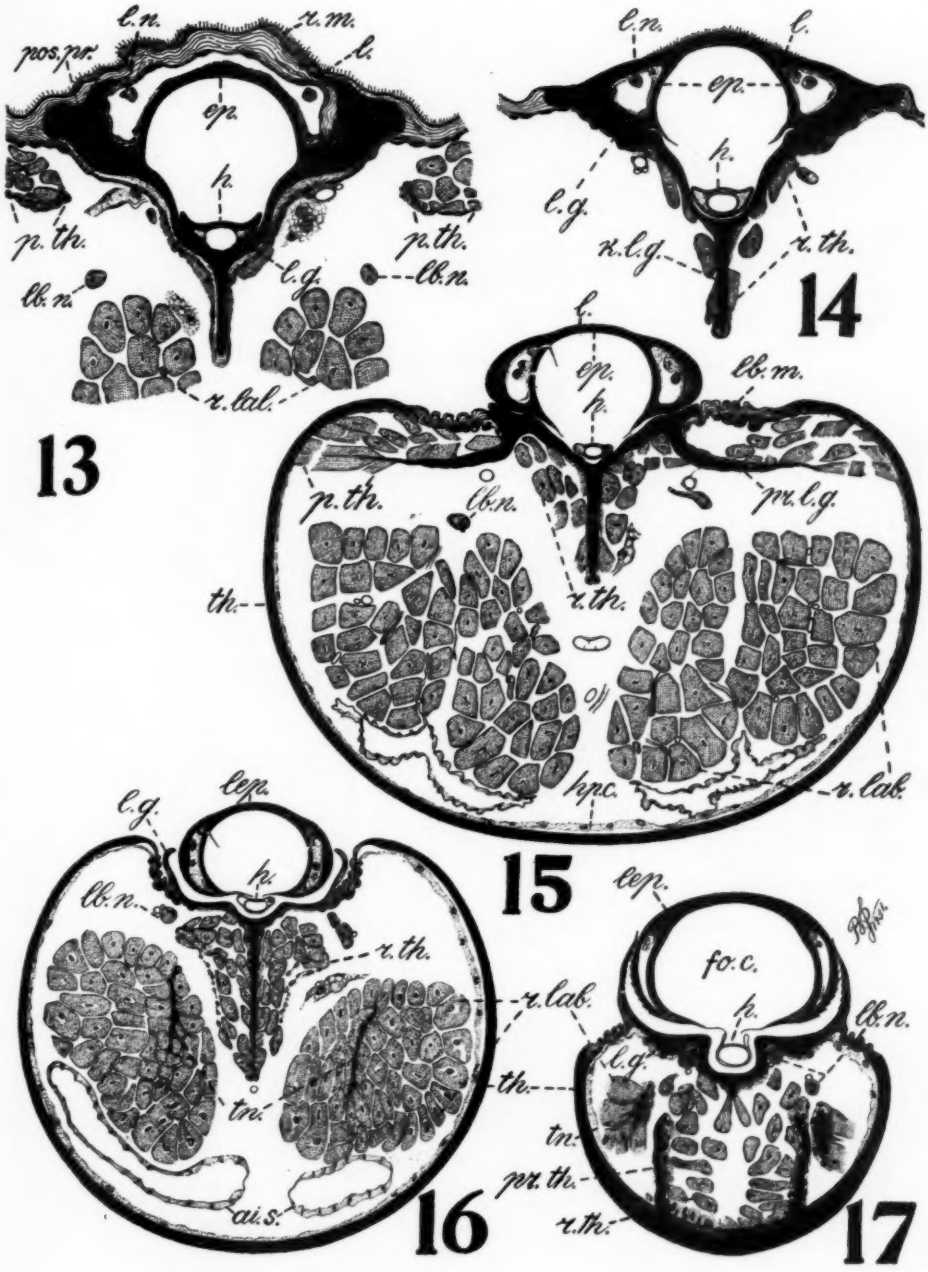
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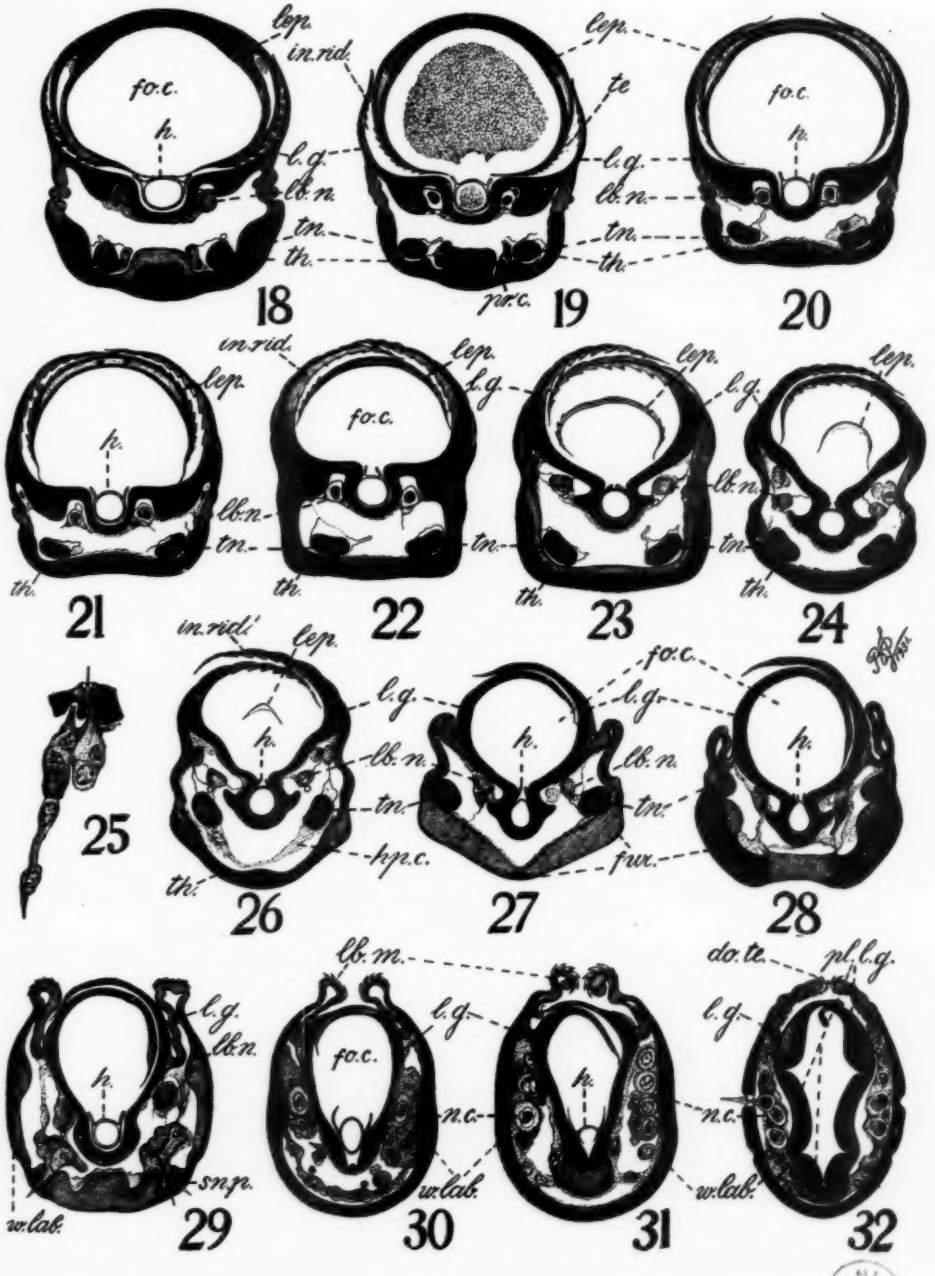
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THE BUCCO-PHARYNGEAL MECHANISM OF A BLOW-FLY LARVA (*CALLIPHORA QUADRIMACULATA* SWED.).

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(With 12 Figures in the Text.)

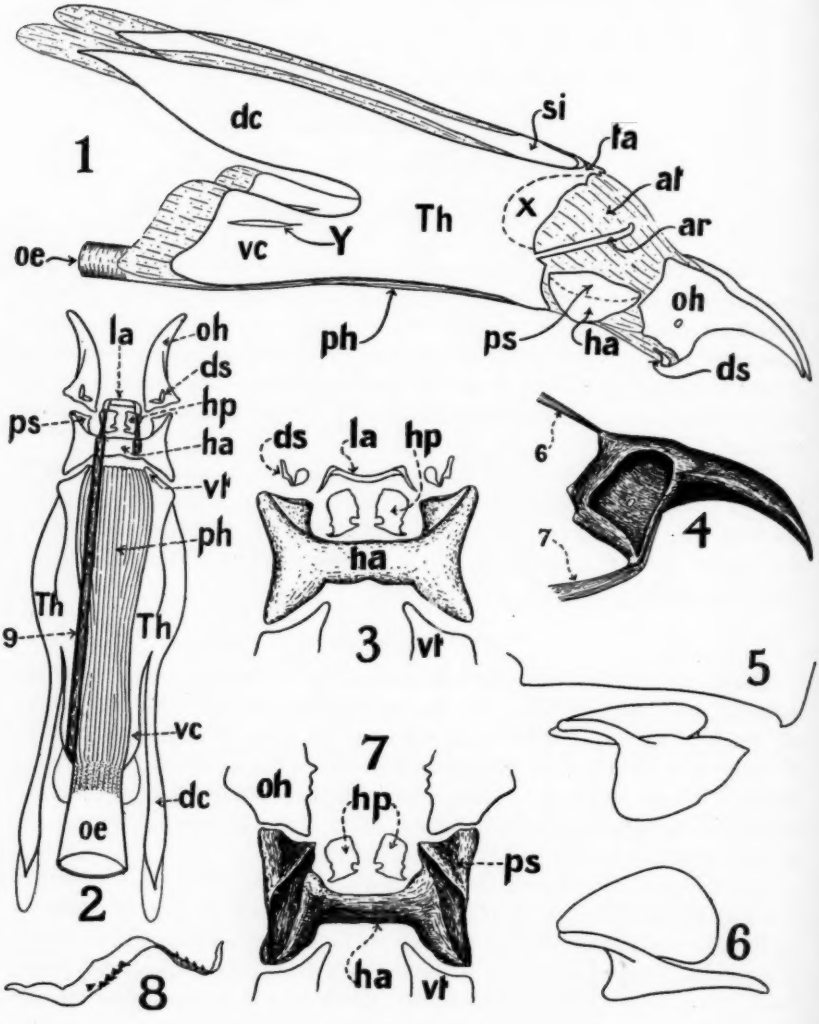
Although much work has already been published on the bucco-pharyngeal mechanism of a blow-fly larva, a close examination reveals the presence of parts hitherto overlooked or but imperfectly recorded. In this account current nomenclature is retained as far as possible; but where the evidence warrants it new terms are employed based on homology, or on the function of the regions concerned, in an endeavour to arrive at a more useful basis for future reference.

The present study is based on the mechanism as it occurs in the adult larva of *Calliphora quadrimaculata* Swed. (the large New Zealand blue-bottle); the structure, which is very constant with but slight modification throughout the related species, consists of (1) the skeleton (Figs. 1–11), and (2) the controlling muscles (Figs. 2, 4, 11 and 12).

(1) The skeleton.

Except for the paired frontal sacs containing the imaginal elements of the antennae and compound eyes, the bucco-pharyngeal skeleton (Fig. 1) encloses the whole of the invaginated head region of the larva. The skeleton consists of three main divisions, (*a*) the strongly chitinised basal portion (*Th*) forming the body of the structure, (*b*) the intermediate membranaceous portion (*at*) supported by several sclerites and enclosing the oral atrium, and (*c*) the anterior portion consisting of the oral hooks (*oh*).

The sclerites (*Th*) forming the body of the skeleton serve as an attachment of the major muscles of the mechanism and prevent the collapse of the pharynx during the absorption of fluid food by suction. They consist of two broad, symmetrical, and vertical plates commonly referred to as the *basal pieces*, *basal plates*, *lateral pharyngeal sclerites* (Hewitt), *cephalo-pharyngeal sclerites* (Lowne), *basal wing plates* plus *posterior lateral plates* (Snodgrass). These two sclerites are narrowly separated, being united only at their upper anterior angles by a strongly chitinised arch (*ta*), the *dorsal sclerite* of Hewitt, and along the full length of their ventral margins by the floor of the longitudinally corrugated pharynx (*ph*, Figs. 1 and 2). In some *Tachinidae*, at least, these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Figs. 1–8.

sclerites are widely separated above and not connected by a dorsal sclerite, but, in such cases, the floor of the pharynx is strongly chitinised; in all the *Calliphoridae* examined by the writer the only part of the pharynx tending to stronger chitinisation is a small posterior area. Since the *dorsal sinus* (*si*), and the pharynx below, together with the dilator muscles of the latter, lie within the lumen formed by these sclerites (*Th*) the writer proposes to name them the *pharyngo-sinusal theca*, and the connecting dorsal sclerite (*ta*) the *dorsal thecal arch*.

Each thecal sclerite is deeply incised posteriorly to form a *dorsal* (*dc*), and a *ventral* (*vc*) *cornu*, the former longer and pointed, the latter shorter and truncate; from both a chitinous membrane projects posteriorly, which, in the case of the *dorsal cornu*, continues forward along the greater length of the dorsal margin of the theca, thus partly closing the intervening space. On the surface of the *ventral cornu* is a distinct longitudinal slit (*Y*) not extending to the posterior border; in the larvae of some muscoid flies, other than calliphorids, this slit is complete, while in others a similar one may occur toward the ventral margin of the *dorsal cornu*, thus forming definite cornual processes.

Anteriorly each thecal sclerite is unevenly truncate, and over the region enclosing the dilator muscles of the pharynx is deeply notched by a depressed and feebly chitinised crescentic area (*x*); the ventral anterior angles of the theca are slightly convergent (*vt*, Figs. 2, 3 and 7) presenting a surface for the articulation of the sclerites supporting the *atrium* (*ps* and *ha*, Figs. 1, 2, 3 and 7).

The intermediate portion of the mechanism (*at*) is a membranaceous extension from the anterior margins of the theca, and of the floor of the pharynx, enclosing the *oral atrium*; the latter narrows towards, and extends

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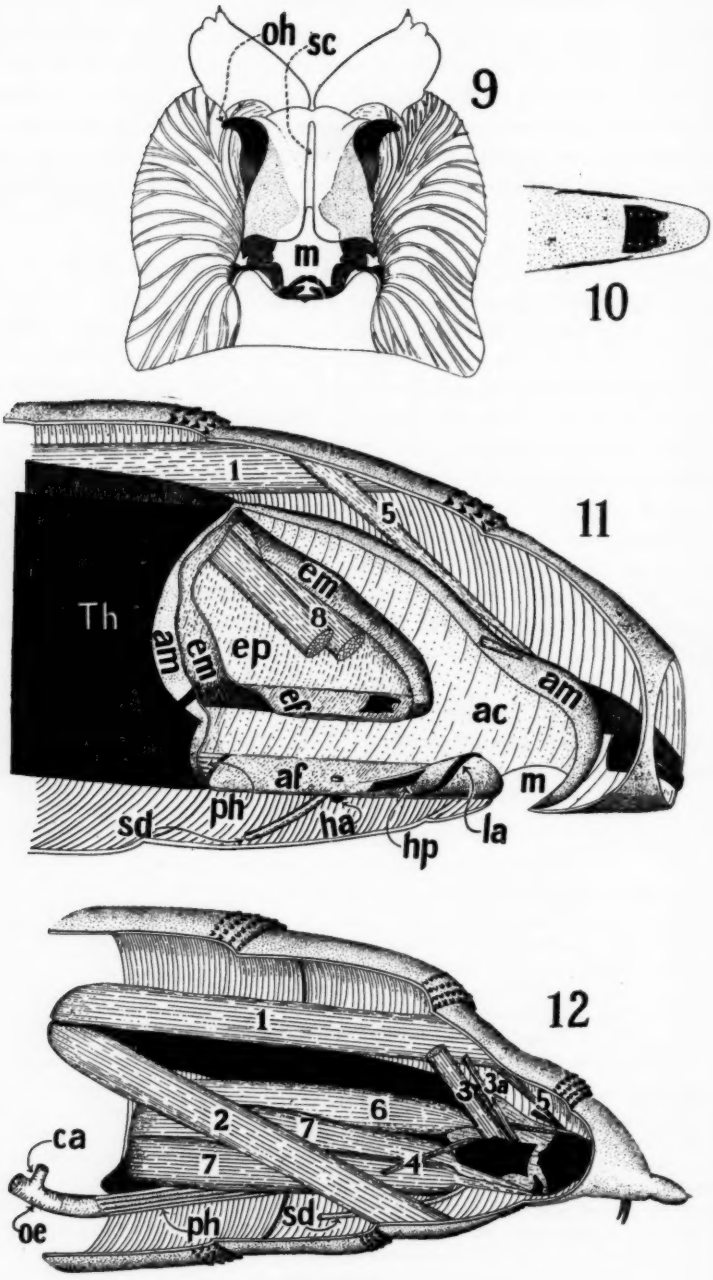
Legends to Figs. 1–8.

Figs. 1–8. *Calliphora quadrimaculata* Swed. (larva).

Fig. 1. The bucco-pharyngeal skeleton.
Fig. 2. Ventral aspect of skeleton.
Fig. 3. Ventral aspect of region in vicinity of hypopharyngeal arch.
Fig. 4. Oral hook showing attachment of muscles.
Fig. 5. Lateral aspect of dentate sclerite.
Fig. 6. Dorsal aspect of same.
Fig. 7. Dorsal aspect of region in vicinity of hypopharyngeal arch.
Fig. 8. Liguloid arch.

Lettering: *ac*. cavity of atrium; *af*, floor of pharynx in atrium; *am*, membrane enclosing atrium; *ar*, atrial rod; *at*, atrium; *ca*, attachment of crop; *dc*, dorsal cornu of theca; *ds*, dentate sclerite; *ef*, epipharynx; *em*, membrane enclosing dilators of epipharynx; *ep*, space occupied by dilator muscles of pharynx and epipharynx; *ha*, hypopharyngeal arch; *hp*, hypopharyngeal plates; *la*, liguloid arch; *m*, mouth; *oe*, oesophagus; *oh*, oral hooks; *ph*, pharynx; *ps*, parastomal sclerite; *sc*, pre-oral sagittal sclerite; *sd*, salivary duct; *si*, dorsal sinus; *ta*, dorsal thecal arch; *Th*, pharyngo-sinusal theca; *vc*, ventral cornu of theca; *vt*, ventral anterior angles of theca; *x*, crescentic notch of theca; *Y*, slit on ventral cornu of theca. 1, dorsal protractor; 2, ventral protractor; 3 and 3 *a*, dorsal retractors; 4, ventral retractor; 5, dilators of atrium; 6, elevator of oral hook; 7, depressor of oral hook; 8, epipharyngeal dilators; 9, liguloid retractors.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Figs. 9–12.

between, the bases of the *oral hooks* (*oh*), where, ventrally, is the wide but short mouth (*m*, Figs. 9 and 11) opening into the cup-like apex of the atrium.

The walls of the atrium are supported by the following sclerites. On each side and arising from the anterior margin of the theca at a point in proximity to the roof of the pharynx, and projecting diagonally forward and upward, is a narrow elongated rod which we term the *atrial rod* (*ar*, Fig. 1); this rod has been named the *parastomal sclerite* (Lowne), *oral rod* (Keilin), *dorsal accessory sclerite* (Thompson), and *arm of anterior lateral* or *triangular plate* (Snodgrass), in reference to the larvae of *Calliphora erythrocephala*, *Anthomyidae*, *Miltogramma punctatum*, and *Rhagoletis pomonella* respectively. The writer, however, considers that a sclerite to be dealt with later on is more fittingly named the *parastomal*, that the terms *oral rod* and *dorsal accessory* are not suitable since the rod is not oral, nor is it actually dorsal, but lateral, and that the term *arm of anterior lateral* or *triangular plate* is misleading in that the rod arises from the theca as clearly seen in the larvae of calliphorids, trypetids, and phycodromids examined by the writer; it is nevertheless possible that the position of the rod varies, since Snodgrass definitely figures and states that it arises from his *anterior lateral plate* (= *ps* and *ha*, Fig. 1) which according to him is fused with the theca in *Rhagoletis pomonella*.

The floor and lower portion of the walls of the atrium are supported by a group of strongly chitinised sclerites (*ps* and *ha*, Figs. 1, 2, 3 and 7), arranged in the form of the letter **H**, the arms of which articulate with the anterior ventral angles of the theca posteriorly, and with the oral hooks anteriorly; this group has been named the *hypostomal sclerite* (Lowne), *intermediate sclerite* (Keilin), **H**-*shaped sclerite* (Thompson), *hypopharyngeal sclerite* (Fuller), and *anterior lateral* or *triangular plate* (Snodgrass). This group of sclerites consists of lateral, more or less vertical plates on each side forming the arms of the letter **H**; these are connected ventrally (Lowne, Fig. 9, illustration 3, shows this connection as dorsal) by a stout transverse arch called by Thompson the *sclerite of the salivary duct*, beneath the floor of the atrium. The salivary duct opens immediately behind this arch, though Hewitt states that the opening is in front in *Musca domestica*. The structure of the sclerites is not altogether clear, but the following parts appear to be present; the ventral transverse arch (*ha*), which is named here the *hypostomal arch*, expands on each side to form the arms of the letter **H**, these lateral expansions, or cornua, extending slightly upwards on to the walls of the atrium; attached dorsally on each side to the cornua of the hypostomal arch is a cuneiform sclerite here

Legends to Figs. 9–12.

Figs. 9–12. *Calliphora quadrimaculata* Swed. (larva).

Fig. 9. Ventral aspect of larval head showing mouth etc.

Fig. 10. Epipharyngeal plate and aciculae.

Fig. 11. Oral atrium, internal view.

Fig. 12. Musculature of mechanism.

(For lettering see Figs. 1–8.)

named the *parastomal sclerite* (*ps*), having its broad end directed anteriorly to form a surface for the articulation of the corresponding oral hook.

Anterior to and between the cornua of the hypostomal arch, and lying just behind the posterior border of the mouth on the floor of the atrium, is a pair of weakly chitinised rectangular plates (*hp*, Figs. 2, 3, 7 and 11) having the inner margin notched near to the posterior angle and the outer posterior angle produced; the writer proposes to call these sclerites the *hypostomal plates*. In *Calliphora stygia* the hypostomal plates are proportionately larger than in *C. quadrimaculata*, and their produced outer posterior angles articulate directly with the hypostomal arch at the angles of the latter and its cornua. Thompson illustrates a single large hypostomal plate (called by him the *hypopharyngeal plate*) in the second stage larva of *Digonochaeta setipennis*.

Between the hypostomal arch and the posterior margin of the mouth, the floor of the atrium is raised in a bulbous manner (*la*, Fig. 11), and when the mouth is closed fits into the cup-like apex of the atrium. On this part, posteriorly, lie the hypostomal plates (*hp*), while anterior to them and forming an arch over the upraised portion is a strap-like sclerite which we propose to call the *liguloid arch* (*la*, Figs. 3 and 11); the lateral extremities of this arch are curved posteriorly and terminate in the vicinity of the cornua of the hypostomal arch, while on the surface of the arch, close to its anterior border on each side, and projecting forward there are distinct, though minute, tooth-like spines (Fig. 8). In *C. stygia* the liguloid arch is broader than in *C. quadrimaculata*, and beset with regular rows of very minute spines. In *Rhagoletis pomonella* Snodgrass shows what he calls the "bridge plate of the pharyngeal skeleton in roof of atrium," in *C. quadrimaculata*, before dissection is made of cleared preparations, the liguloid arch is visible through the membrane of the atrium, and at first sight might be mistaken for a sclerite similar to such a bridge plate; in the Trypetidae examined we have been unable to locate this bridge plate, but in *Coelopa* (Phycodromidae) such a plate does exist in the membrane of the atrium and could be conveniently named the *epistomal plate*. Thompson, in the second stage larva of *Digonochaeta setipennis*, records his epipharyngeal plate "which is in the upper wall of the buccal cavity or atrium," and this may be the homologue of the epistomal plate named above. In the same species Thompson also shows that the cornua of the hypostomal arch are anteriorly united near their extremities by a transverse band, probably the homologue of the liguloid arch.

The *oral hooks* (*mandibular hooks* or *sclerites*, *lateral hooks*) are a pair of very strongly chitinised laterally compressed sclerites lying, with their broad faces opposed, on each side of the mouth (*oh*, Figs. 1, 3 and 7); each hook consists of a large body or basal portion articulated with its corresponding parastomal sclerite, and an elongated pointed hook or anterior portion, the apex of which projects from the surface of the integument anterior to and on each side of the mouth (Fig. 9); on the outer surface of the basal portion of each hook is a large cavity (Fig. 4) where the chitin is pierced by a conspicuous

more or less central aperture; this cavity contains the cells proliferating the hook (Thompson). In the cuticle, between the oral hooks, and extending forward from the anterior oral margin, is a narrow median area not heavily chitinised in *C. quadrimaculata* (*sc*, Fig. 9); in other species of the genus, however, this area is strongly chitinised to form what is here called the *pre-oral sagittal sclerite*, the pointed apex of which projects from the surface of the cuticle.

Ventrally and close to the base of each oral hook, lying in the membrane at the lateral angles of the mouth, is the small *dentate sclerite* of authors (*ds*, Figs. 1, 2 and 3). This sclerite is not a simple one as generally shown, but consists of two pyriform pieces set almost at right angles to one another; in profile (Fig. 5) the ventral one, having its external face convex and its internal concave, lies vertically, while the dorsal one, which is practically flat, lies horizontally; the two are connected by a curved arm arising from the upper margin of the ventral piece and extending backwards to unite with the posterior extremity of the dorsal piece (Fig. 6).

In addition to the sclerites already discussed there are others lying within the atrium itself. When the latter is opened there will be found projecting into it from the muscle-packed region above the pharynx, a tongue-like process (*em*, Fig. 11) the ventral face of which is a forward continuation of the roof of the larval pharynx. As shown by Pratt, in his study of the embryology of *Melophagus ovinus*, this process is the invaginated labrum. On the ventral face of the latter (*ef*, Fig. 11), near to its apex, lies a small rectangular sclerite (Fig. 10) having its anterior angles prolonged as a pair of short processes, while toward its lateral margins is a row of four perforations fed by a pair of nerves each of which divides into four branches, this sclerite is obviously sensory and we propose to name it the *epipharyngeal plate*. Extending back from this plate on each side is a sinuated needle-shaped sclerite (Fig. 10); these are here named the *epipharyngeal aciculae*.

(2) THE MUSCULATURE.

The bucco-pharyngeal skeleton is controlled by a simple set of muscles (Fig. 12). The most conspicuous of these, practically obscuring the pharyngo-sinusal theca to which they are attached, are the protractors of the bucco-pharyngeal apparatus, and beneath them the elevators and depressors of the oral hooks. The protractors are attached posteriorly to the dorsal cornua of the theca and consist of the dorsal (1) and *ventral* (2) *protractors*, the former extending to the dorsal, and the latter to the ventral body wall of the first thoracic segment. The muscles of the oral hooks arise posteriorly from the ventral cornua of the theca, the *elevators* (6) being attached to the dorsal posterior angles of the hooks, and the *depressors* (7) to the opposite ventral angles by tendon-like terminations. It is said by Thompson and Hewitt that the depressors are attached to the dentate sclerites, but our observations

agree with those of Snodgrass in that the attachment is with the oral hooks (Fig. 4).

Arising from the dorsal border of the parastomal sclerites are three muscles on each side; two of these (3 and 3 *a*) run upward and backward, while the third (4) is directed downward and backward. These are part of the group of muscles referred to by Hewitt as *stomal dilators*, and are doubtless the six slender muscles which Snodgrass states to be inserted in the membranous roof of the atrium between the "prongs" (atrial rods) of the "triangular plate" (parastomal sclerites); from their attachment and direction they cannot be considered as dilators, and since there is but little or no elasticity in that part of the atrium owing to rigidity given by the parastomal sclerites and hypostomal arch, it is more feasible to consider them as *dorsal* (3 and 3 *a*) and *ventral* (4) *bucco-pharyngeal retractors*; apart from the body retractors attached to the anterior margin of the first thoracic segment there is no other visible means for the retraction of the larval head and bucco-pharyngeal skeleton.

Attached to the roof of the oral atrium between the base of the oral hooks is a pair of slender, divergent, and retrose muscles (5) called the *elevators of the upper-lip* by Thompson; since the term "upper lip" is misleading in that the homologue of the labrum lies within the atrium, since the anterior oral margin of the larva, which might be considered the larval upper lip, remains stationary, the mouth being opened and closed by backward and forward movements of the liguloid arch respectively, and owing to the attachment of these muscles to the dorsal wall of the atrium immediately over the mouth, we prefer to consider them the *dorsal dilators* of the atrium. Hewitt's *mandibular extensor*, from its position shown in his figure (19, Pl. 31) seems to represent a dorsal dilator rather than a muscle of an oral hook, though an elevator of the latter could hardly be missed owing to its size and attachment to the theca; but some confusion seems to exist in Hewitt's work since he states that only one oral hook is to be found in the larva of *Musca domestica*.

Ventrally, running from the ventral cornua of the theca, on each side of the pharynx, to the liguloid arch is a pair of slender muscles (9, Fig. 2). Thompson names these the *labial retractors*; but since the liguloid area operated by these muscles can hardly be considered as the homologue of the labium (the imaginal buds of which lie more posteriorly in the vicinity of the hypostomal arch) a more correct name would be *liguloid retractors*.

The muscle-packed region above the pharynx and enclosed by the pharyngosinusal theca is referred to by authors as the *dorsal sinus*, *pharyngeal sinus*, or *dorsal pouch*; these terms are misleading since the dorsal sinus is a narrow space between the muscles and the thecal sclerites and opens into the atrium; it originates as a separate invagination in the embryo. Judging from Pratt's researches, the muscles of the region in question are those controlling the invaginated labrum and thus the whole of the larval pharynx within the theca is really the labrum; the anterior and posterior sets of these muscles run diagonally forward and backward respectively, while the median ones are

vertical; since the median and posterior sets control the larval pharynx the name *pharyngeal dilators* may be conveniently retained, but since the anterior set (8, Fig. 11) clearly controls the epipharyngeal plate, these muscles may be rightly called the *epipharyngeal dilators*. In the absence of opposing muscles the dilators of the pharynx, epipharynx and atrium, and the liguloid retractors are counteracted by the resilience of the chitinous membranes to which they are attached.

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STUDIES ON AVIAN CESTODES FROM CHINA.

PART II.
CESTODES FROM CHARADRIIFORM BIRDS.

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(With Figures 38–54 in the Text.)

Part I of these studies on the cestodes from Charadriiform birds of China appeared in this *Journal* in March 1932[1]. Here nine more species of the same lot from Peking are dealt with. The names of hosts, specimen numbers, and the month in which they were collected are stated in Part I.

Family *HYMENOLEPIDIDAE*.

Genus **Haploparaxis** Clerc.

Haploparaxis sinensis n.sp. (Figs. 38–41).

Host: *Scolopax rusticola*.

Locality: Peking, China.

Specimen: Pe 751.

Tube Pe 751 contained two kinds of slender tapeworms, mostly with rostellum bearing ten hooks, characteristic of *Haploparaxis*.

Length 140 mm., breadth 1 mm. Scolex 0·276 mm. in diameter; rostellum 0·171 × 0·102 mm.; sucker 0·084–0·100 mm. in diameter; ten rostellar hooks 0·027–0·036 mm. long; rostellar sac 0·1596 mm. long, extending a little beyond sucker. Neck present. Young segment measuring 0·1482 × 0·0114 mm., mature segment 0·850 × 0·153 mm., gravid segment 0·986 × 0·221 mm. Genital pore unilateral, at middle of proglottis margin. Cirrus sac long, 0·285 × 0·022 mm., extending medially half-way between the middle line of the proglottides and poral excretory vessels or passed beyond the former. Testis single, 0·342 mm. in diameter. External seminal vesicle extending from internal end of cirrus pouch, first short and narrow, later swelling up into a globular sac overlain ventally by ovary. Ovary lobed, 0·228 mm. in transverse diameter, situated between testis and vitelline gland. Form of vitelline gland and ovary changeable in successive mature segments. Vagina running inward dorsally to cirrus sac, near poral lobe of ovary forming into seminal receptacle. Dorsal excretory vessel (0·020 mm. diam.) and ventral excretory vessel (0·028 mm.) passing dorsally to genital ducts. Uterus sac-shaped. Onchospheres of two shells:

[1] Tseng, S., *Parasitology*, **24**, 87–106, with Figures 1–37 in the text.

external shell rounded in young state, lemon-shaped in mature stage, armed with two polar plugs, measuring 0·052 × 0·043 mm. Internal shell always rounded, 0·032 mm. in diameter. Embryo 0·028 mm. diam. and embryonal hooklets 0·016 mm. long.

Up to now the number of species of *Haploparaxis* Clerc, has increased to sixteen. For chief characters of different species see Table II. According to previous authors, rostellar hooks, internal longitudinal muscles, cirrus pouch and eggs were considered as principal of characteristics in classifying species. In spite of the great similarities in the forms of the rostellar hooks in most species of *Haploparaxis*, they remain of primary importance in classification. The number of external longitudinal muscles in *Haploparaxis* spp. is comparatively constant, while that of the internal longitudinal muscles is very variable, ranging from 8, 12, 16, 18, 20, 24, 30, 38, 40, 50, to 60. Their cirrus pouches may be divided into three distinct categories: *H. penetrans*, *H. crassirostris*, *H. pseudofilum*, *H. fuligulosa*, *H. australis*, *H. larina* and *H. birulai* all have a small cirrus pouch, less than one-third the width of proglottis; while the cirrus pouch in *H. cirrosa* and *H. hirsuta* extends medially to the excretory vessel of the antiporal side. The other species such as, *H. filum*, *H. brachyphallos*, *H. elisae*, *H. dujardinii*, *H. diminuens* and *H. sinensis* this organ is of moderate length, *i.e.* it extends up to the middle line or beyond.

The eggs of *Haploparaxis* spp., as indicated by Clerc (1903), seem to have three forms: *H. cirrosa*, *H. crassirostris*, for instance, have rounded eggs, *H. pseudofilum* has eggs devoid of the same distinguishable polar thickness as found in eggs of *H. filum* (as outlined by Clerc, 1903, in text-figs. 2, 3). Since then, Johnston was the only worker who pointed out in describing *H. australis* that his species has eggs resembling those of *A. filum* and figured one egg (fig. 31, pl. XVI, 1911) with polar thickness more prominent than Clerc's figure. In carefully examining the eggs of *H. sinensis* in the hope of determining their special form, I was surprised to find that all three forms are represented, as shown in Fig. 41, *a*, *b*, *c* (drawn under camera lucida): *a*, with external shell round; *b*, with two polar thickenings less developed than in *c*, but on one extremity, at the side of polar plug, a slight slit can be seen. The polar plugs appear completely formed in well-matured eggs (*c*). This slit around the polar plugs will facilitate the exit of the embryo.

Hymenolepis himantopodis (Krabbe 1869).

Host: *Totanus calidris*.

Locality: Peking, China.

Specimen: Pe 1459.

Length 70 mm., maximum breadth 1·5 mm., each proglottis broader than long. Scolex 0·364 × 0·228 mm., rostellum 0·060 mm. diam., rostellar sheath small and short, 0·160 mm. long; neck present, about 0·285 mm. long; suckers, 0·128–0·132 mm. diam., slightly projecting from surface; ten to twelve rostellar hooks, 0·009 mm. long. Cirrus sac narrow, in mature proglottides half-

way across their width (agrees with Meggitt's description, 1927). Vagina parallel to cirrus sac posteriorly. Receptaculum seminis small. Ovary elongated transversely, its position rather variable. Vitelline gland 0·1026–0·114 × 0·0456–0·0680 mm., irregular form, ventral to ovary. Testes large, 0·064 mm. diam., arranged in a transverse row.

Hymenolepis nitida (Krabbe 1869) Clerc 1902 (Fig. 42).

Syn.: *Taenia nitida* Krabbe 1869.
Echinocotyle nitida Clerc 1902.

Host: *Tringa* spp.

Locality: Peking, China.

Specimen: Pe 828.

In tube Pe 828 were found a few scolices. The scolices appear identical with those in the present species.

Scolex 0·192 mm. diam., measuring on level of suckers; rostellum 0·156 × 0·060 mm.; suckers 0·128–0·140 × 0·068–0·076 mm.; neck 0·060 mm., in width; 1st segment 0·120 × 0·020 mm. ten rostellar hooks, 0·076–0·080 mm. long. Acetabular hooks present, arranged in four rows on the lateral edges of suckers, two or one on the posterior and anterior edges, and three or four at their bases.

Hymenolepis sp. (Fig. 43).

Host: *Tringa* sp.

Locality: Peking, China.

Specimen: Pe 828.

In company with a few scolices of *H. nitida* were found some deep black strobilae which, after being treated with solutions for dispigmentation, show three testes (0·086 mm. diam.) arranged nearly in a transverse line. Notwithstanding that the other structures are not clearly observed, some observations regarding anatomy may be mentioned here. The genital pore is sub-marginal and unilateral. The edge of the genital aperture is furnished with a row of hooklets (0·0054 mm. long). In the genital atrium, the vagina, when

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Legends to Figs. 38–46 and 54.

Figs. 38–41. *Haploparaxis sinensis* n.sp. (38) Scolex and portion of strobila. (39) Rostellar hooks. (40) Mature segment. (41) Different stage of egg: *a*, egg with external shell rounded; *b*, egg with polar thickness not well developed; *c*, egg with polar plugs completely formed.

Fig. 42. *Hymenolepis nitida* (Krabbe). Scolex showing rostellum mounted with hooks and suckers armed.

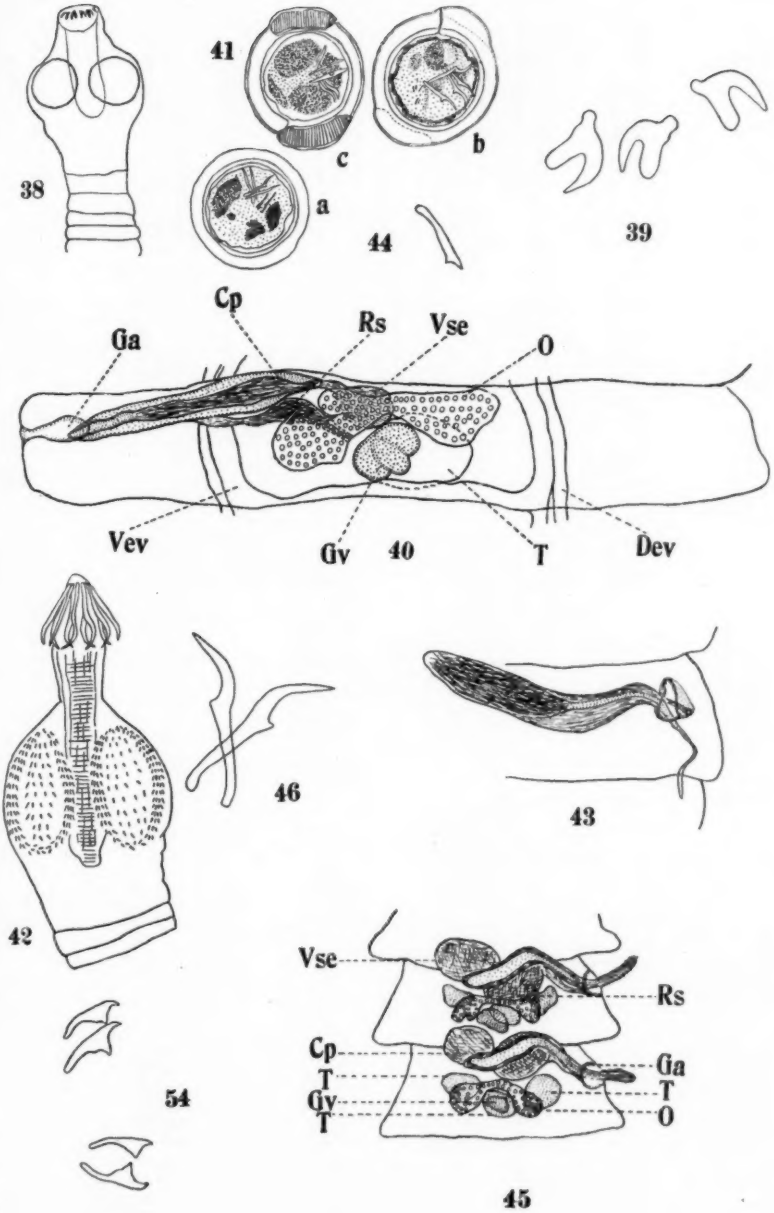
Fig. 43. *Hymenolepis* sp. Portion of mature segment showing genital atrium armed with delicate hooklets at its edge and cirrus protracting into the successive segment.

Fig. 44, 45. *Fuhrmanniella clerci* n.sp. (44) Rostellar hooks. (45) Mature segments.

Fig. 46. *Fuhrmanniella uralensis* (Clerc). Rostellar hooks.

Fig. 54. Rostellar hooks of a tapeworm from the liver of *Totanus calidris*.

Lettering to figures: *Cp.* Cirrus pouch; *Dev.* Dorsal excretory vessel; *Ga.* Genital atrium; *Gv.* Vitelline gland; *O.* Ovary; *Rs.* Receptaculum seminis; *T.* Testes; *Vev.* Ventral excretory vessel; *Vse.* External seminal vesicle.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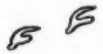
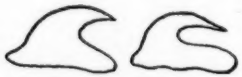
Species of Haploparaxis from Birds

Species	Hooks: No.	Hooks: Size (mm.)	Hooks: Form	Internal longitudinal muscles	Cirrus pouch	Eggs	Host	Locality
H. furcigera Duj. 1845 (*T. rhomboidea*, Krabbe 1869	10	0·048–0·056 or 0·065–0·066 long		8 bundles	—	0·036 mm. diam. embryonal hooklets 0·014 mm.	*Anas crecca, Anas boscas, Nyroca ferina*	Northern Europe and Turkestan
H. penetrans Clerc 1902	10	0·040 long		50–60	Small, less than 1/3 width of segment	Middle shell devoid of thickness	*Tringa minuta Gallinago gallinago*	Ural
H. crassirostris Clerc 1903 (Krabbe 1869)	10	0·033 long		24–30	,,	,,	*Charadrius, Squatarola, Scolopax, Phalaropus, Tringa, Tringoides, Totanus, Gallinago*	Europe
H. pseudofilum Clerc 1902	10	0·017–0·019 long		12–18	,,	Without sharp demarcation of polar thickness at middle shell	*Tringa, Totanus*	Ural
H. filum Clerc. 1903 *T. filum* Gœze 1782)	10	0·017–0·0185 long		On both dorsal and ventral side 5–7 between excretory vessels and 1–2 lateral to them	Very large, extending to middle line or beyond	Three shells, of which the middle one thick and furnished with ring-like thickness at each end	*Arenaria, Phalaropus, Tringa, Tringoides, Totanus, Numenius, Scolopax, Gallinago*	Northern Europe and Italy
H. cirrosa Clerc 1903 (*T. cirrosa* Krabbe 1869)	10	0·024 long		16–18	As large as that of *H. hirsuta*	?	*Larus minutus, L. canus, L. ridibundus, Sterna hirundo*	Northern Europe
H. brachyphallos (Krabbe 1869) (*H. brachyphallos* Fuhrm, *Skorikowia clausa* von Linst, *Diorchis serpentata* von Linst)	10	0·017–0·018 (0·026) long			Near middle line or beyond	Slightly oval, outer shell 0·036 × 0·034, middle, thick shell 0·026 × 0·021–0·023 mm.	*Charadrius, Tringa, Arquatella*	Northern Europe
H. hirsuta Clerc 1903 (*T. pubescens* Krabbe 1882, *Monorchis hirsuta* Clerc 1902	10	0·037–0·044 long		24–30	Very large, almost reaching excretory vessels of the aporal side	Middle shell devoid of thickness	*Totanus, Gallinago*	Europe
H. fuligulosa Soloviow 1911	?				0·073 × 0·0932–0·0139 – 0·019 mm.	0·0559 mm. diam. hooklets 0·0139–0·0163 mm. long	*Fuligula cristata*	Europe

					side			
H. fuligulosa Solowiow 1911	?				0·073 × 0·0932–0·0139 – 0·019 mm.	0·0559 mm. diam. hooklets 0·0139–0·0163 mm. long	*Fuligula cristata*	Europe
H. larina Fuhrm. 1920	10	0·216–0·023 long		10 dorsal, 10 ventral (6 between excretory vessels and 2 lateral on each side	A little passed excretory vessels	0·024 mm. diam., outer shell 0·04 mm. diam.	*Larus dominicanus*	South Pole
H. murmanica Baylis 1919	10	0·065 long		—	—	0·020 mm.	*Somateria mollissima*	Murman coast (Arctic Russia)
H. elisae Skrjabin 1914	10	0·0259 long		—	0·25–0·26 × 0·023–0·025 mm. reaching middle line	0·026–0·003 mm.	*Fuligula nyroca*	Russian Turkestan
H. australis Johnston 1911	8	0·19–0·22 long		Few but larger	Short 0·045 mm.	Egg like that of *H. filim*, 0·057 × 0·042 mm., onchosphere 0·034 × 0·025 mm. hooklets 0·15 mm. long	*Gallinago australis*	North Queensland (Australia)
H. dujardinii (Krabbe 1869) Clerc 1903	46	0·016–0·018 long		50–60	Long	3 shells, 2 internal rounded, external variable	*Sturnus vulgaris*	Northern Europe
H. birulai v. Linstow 1905	10	0·032 long		38?	Nearly 1/3 width of proglottides	0·040 × 0·034 mm.	*Erionetta spectabilis*	Russia
H. diminuens v. Linstow 1905	10	0·0143 long		41?	More than half width of proglottides	Outer shell 0·047 × 0·031 mm., inner 0·031 × 0·029 mm.	*Crymophilus fulicarius*	Russia
H. sinensis mihi	10	0·27–0·36 long		2 lateral, 3–5 medial to excretory vessels on both dorsal and ventral sides	0·285 × 0·027 mm. extending to middle line or beyond	Onchosphere 0·0288 mm., hooklets 0·0162 mm.	*Scolopax rusticola*	Peking, China

protruded, can sometimes be seen also armed with delicate spines only at the end. From the atrium a long and large cirrus pouch (0·220 × 0·024 mm.) extends inwards across the entire width of segment, the pouch being longer than that of *H.* (*E.*) *nitida* (*fide* Clerc, 1903, p. 313: "La poche du cirrhe se continue à peu près jusqu'au centre du proglottis.") Sometimes the cirrus pouch bends towards itself midway or runs obliquely directing its aporal extremity into the preceding segment. The inside of the cirrus pouch is mostly occupied by the seminal vesicle. The penis, when protruded, can be seen penetrating into the parenchyma. Under this condition, it may be expected that fecundation would have occasionally taken place through the parenchyma. No accessory sacculus, similar to those described by Clerc in certain *Echinocotyle*, has been detected so far as I am aware.

Hymenolepis sp.

Host: *Gallinago media*.
Locality: Peking, China.
Specimen: Pe 748.

Tube Pe 748 contained two tapeworms of which all the rostellar hooks are gone and the strobilae are much macerated. The present specimen possess three testes 0·017 mm. in diam., arranged in two poral and one aporal or two lateral and one middle. Genital pores are unilateral and the cirrus sac measures 0·342 mm. long across one-third the transverse diameter of the proglottis. Other details can not be satisfactorily seen.

Weinlandia styloides (Fuhrm. 1906).

Syn.: *Hymenolepis styloïdes* Fuhrm. 1906.
Host: *Rhynchaea capensis*.
Locality: Peking, China.
Specimen: Pe 1490.

Length 20 mm., breadth 0·68 mm. Scolex 0· 1938 mm. diam.; rostellum 0·057 mm. diam., carrying ten hooks, 0·03 mm. long; rostellar sac 0·4278 mm. long; suckers 0·114–0·159 mm. diam. Testes three in number, 0·1 mm. diam. one poral and two aporal, one of the latter anterior to the other. Cirrus pouch 0·255 × 0·068 mm. Eggs 0·044 mm. diam.

So far as the material is serviceable for comparison, the above characters observed are in agreement with *H. styloïdes* Fuhrm, recorded from *Vanellus aegypticus*.

Fuhrmanniella clerci n. sp. (Figs. 44–45).

Host: *Rhynchaea capensis*.
Locality: Peking, China.
Specimen: Pe 750.

Length 60 mm., maximum breadth 1·00 mm., all segments broader than long, genital anlage beginning at about 80th segment. Scolex sub-globular, 0·262 mm. diam.; suckers 0·102 mm. diam.; hooks ten, 0·027–0·0288 mm. long;

rostellar sheath extending backwards just to the posterior side of suckers. Genital pore anterior to centre of proglottis margin. Genital atrium distinguishable, cirrus armed. Cirrus sac long, reaching antiporal testes, across two-thirds of proglottis, bending anteriorly upon itself, length from pore to bend 0·228 mm. from bend to inner extremity 0·168 mm., total 0·396 mm. and maximum breadth 0·060 mm. Testes three, 0·114–0·136 mm. diam., one poral, one middle, one aporal, the lateral two rather forward. Ovary bilobed, poral lobe a little smaller than aporal, situated anteriorly at middle testis. Vitelline gland at ventral side, just under or a little posterior to middle testis. Vagina, dorsal to cirrus sac, bending anteriorly from atrium and swelling into a large receptaculum seminis. Receptaculum seminis 0·205 × 0·17 mm., in front of ovary, at mature segments its anterior side reaching anterior margin of proglottis. Uterus sac-like. Onchospheres with two shells: 1st, 0·025–0·027 mm. diam., 2nd, 0·048–0·054 mm. diam.

Judging from the characters of rostellar hooks alone, the present specimen seems near *H. interrupta* Rud., but its internal anatomy, particularly the disposition of testes, indicates a very characteristic pattern which is closely related to *E. uralensis* Clerc, *H. clausa* v. Linstow, *H. terraereginae* Johnston and *H. fasciata* Rud. They were considered by Mayhew (1924) as "Species inquirendae." If the manner of the disposition of testes plays an important part in the classification of this group of tapeworms, it is necessary to create a new genus, *Fuhrmanniella*, for receiving all the species not yet arrayed with three testes, placed in different planes, two marginal anterior and one median posterior, characters as indicated by Clerc (1903) in studying *Echinocotyle uralensis*. The diagnosis of this new genus is as follows:

> Three testes, the first two arranged in a marginal anterior position and the third, median posterior. Genital pores unilateral. Rostellum armed with a simple crown of hooks. Genital ducts pass dorsally to the longitudinal excretory vessels. Vas deferens with an internal and an external seminal vesicle.
>
> Type species: *Fuhrmanniella uralensis* (Clerc 1902).

In comparison with the above four species, none has any character resembling the present species, except the arrangement of testes.

Fuhrmanniella uralensis (Clerc 1902) (Fig. 46).

Syn.: *Echinocotyle uralensis* Clerc 1902.

Host: *Tringa americana*.

Locality: Peking, China.

Specimen: Pe 884 *a*.

Pe 884 *a* contained only a few scolices with remarkable hooks.

Scolex 0·228 mm. diam.; rostellum 0·126 mm. diam.; rostellar sac 0·171 × 0·045 mm.; suckers 0·084 mm. diam.; neck 0·102 × 0·136 mm.; 1st segment 0·140 × 0·016 mm.; ten rostellar hooks, 0·054–0·057–0·059 mm. long. Acetabular hooks indistinct.

The rostellar hooks of this specimen are similar in shape to those of *E. uralensis* Clerc = *F. uralensis* (Clerc) and of the same size as those of *E. nitidulans* (Krabbe). As the shape of rostellar hooks is generally less variable than the size, it seems better to refer the specimen to *F. uralensis* (Clerc).

Fam. *ACOLEÏDAE.*

Genus **Gyrocoelia** Fuhrm.

Gyrocoelia fausti n.sp. (Figs. 47–53).

Host: *Lobivanellus cinereus and Rhynchea capensis.*

Locality: Peking, China.

Specimen: Pe 703 *a*, 691 *a*, 1428 *a*, 1437, 1440 *c*, 1450 *b*, 85 and 126.

Length 170 mm., maximum breadth 8 mm. Scolex 0·513 × 0·228 mm.; rostellum 0·0912 mm. diam., carrying sixty-six hooks 0·0216–0·0486 mm. long, arranged in zigzag form (Fig. 47), characteristic of *Gyrocoelia*; suckers 0·276 mm. diam.; rostellar sac short and small, posterior extremity reaching only to the posterior level of suckers; neck present, very short 0·547 × 0·091 mm. Young segments measuring 0·558 × 0·045 mm., mature 1·1 × 0·765 mm., gravid 7–8 × 2 mm. Anlage of genital organs beginning at about 10th segments behind scolex. Longitudinal bundles consisting of two concentric series on both dorsal and ventral sides: the outer of which shows 100–130 bundles, 0·017–0·091 mm. diam., each with about thirty fibres; while the inner series shows 100–120 bundles, 0·021–0·120 mm. diam., about fifty fibres, the lateral bundles smaller than the central, particularly those above and below cirrus sac. Transverse fibres in three distinct layers alternating with two layers of longitudinal muscles, but the innermost layer seems more or less feeble. Two pairs of longitudinal excretory vessels, lumen of dorsal vessels measuring 0·022 mm., of ventral 0·034 mm., each pair communicating by a transverse vessel. Cirrus pouch passing between dorsal and ventral excretory vessels. Male genital opening irregularly alternate, in front of centre of proglottis margin. Cirrus pouch 0·629 × 0·255 mm., cirrus, when protruded, 0·510 × 0·054–0·085 mm., armed with four kinds of hooklets (Fig. 50). Testes forty-two to forty-eight in number 0·051–0·114 mm. diam., seemingly grouping into two series, present in anterior segments of 1·610 × 0·850 mm. or 1·460 × 1·139 mm. Vasa efferentia conjoining with two main ducts, which are reunited and form into a simple coarse vas deferens. Internal seminal vesicle folding up in cirrus pouch. No vagina. Ovary large and broad, of two lobes, 1·275 × 0·170 mm., well developed in segments of about 2·210 × 0·340 mm. Vitelline gland bilobed 0·456 × 0·119 mm., posterior to ovary. Uterus ring-like, measuring 1·530 × 0·170 mm. in circumference. Shell gland 0·114 mm. diam., partially overlaid by vitelline gland. Eggs with two shells; external 0·064 × 0·043 mm., internal 0·043 × 0·030 mm., onchosphere 0·039 × 0·025 mm., embryonal hooklets 0·012 mm. long (Fig. 53).

Pe 1450 *b*, Pe 1428 *a*, Pe 1437, Pe 1440 *c* and Pe 126 contain the same

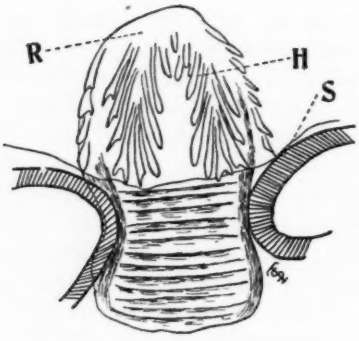
species, but in each entire strobila no testes are found, although the cirrus pouch and the female organs have developed. This form is likewise different from the genus *Dioicocestus* which is characterised by a separation of sex, provided with a single female or two male organs. Such a peculiarity was also observed by Clausen (1915) in the strobilae of *G. paradoxa* (von Linstow). Among the five female strobilae mentioned above, No. 1428 *a* mounted in balsam is a complete worm upon which the following account is based: The length of whole strobila is 137 mm. The gravid segments (eggs not well developed) measure 6·0 mm. wide by 0·595 mm. long, mature ones 3·0 by 0·34 mm. (9 : 1) and the youngest ones closely behind the scolex 0·527 mm. by 0·017 mm. The scolex is 0·084 mm. in diam. Unfortunately, the rostellar hooks are absent. The neck is present, measuring 0·408 mm. by 0·170 mm. The anlage of genital organs begins at the 8th segment; at about the 60th segment, the cirrus pouch, ovary and vitelline gland begin to differentiate; at about the 140th segment, the cirrus pouch, ovary, vitelline gland and shell gland are fully developed and the uterus is well marked at about the 250th segment. At the last segments, the uterus is filled up with developed eggs. This indicates that cross-fertilisation has taken place. In the gravid segment the cirrus pouch, in spite of being sterile, reaches the same size as that of the above mentioned double-sexed strobilae (0·627 × 0·250 mm.). Finally, all the segments found in the only female strobila are broader than long, while the anterior segments (with testes) of the double-sexed strobilae are sometimes as wide as they are long. This fact also confirms Clausen's observation of *G. paradoxa*.

Up to the present, this genus only includes five known species from five Continents, namely, *G. perversus* Fuhrm. from Europe, *G. leuce* Fuhrm., South America, *G. brevis* Fuhrm., Africa, *G. australiensis* Johnston, Australia and *G. paradoxa* (von Linstow), Asia (India). In 1922, Maplestone and Southwell described a species of the Genus *Gyrocoelia* under the name of *G. australiensis* which, for the first time was observed by Johnston, as possessing only five testes. Both material described by Johnston and by Maplestone and Southwell lack the rostellar hooks. The present species from Peking has some similarity to Mapleston and Southwell's specimen, but differs from Johnston's in the slow appearance of the uterus (see Johnston, 1912, p. 30: "the genitalia appear very early, the uterus and the other parts being recognised in the youngest segments examined") and numerous testes. Therefore, *G. australiensis* differs from the present species, and it is reasonable to create a new species for Faust's specimens from Peking.

SUMMARY.

In conclusion, the following comments may prove suggestive:

1. Out of fifty-five vials of the Chinese cestodes from Charadriiform birds, fifteen have not been determined definitely, owing to the poorly preserved condition and to insufficient material for detailed study, such as Pe 510, Pe 517,



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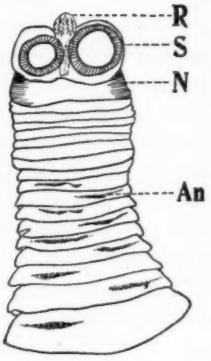

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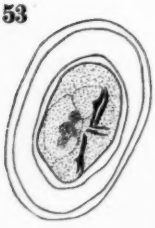

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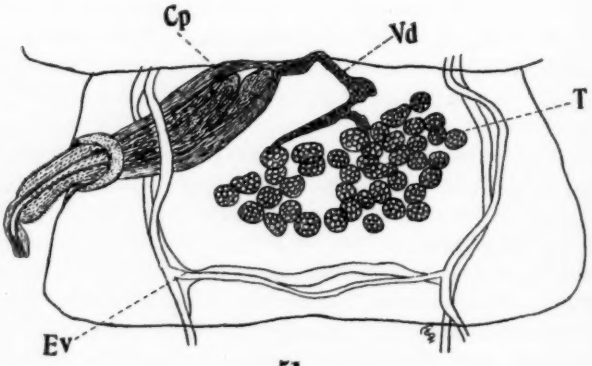

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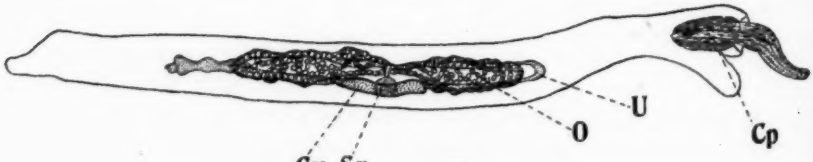

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Pe 526, Pe 529, Pe 552 *b*, Pe 588, Pe 593, Pe 1466, Pe 735 *c*, Pe 1431 *d*, Pe 760, Pe 144 *b*, Pe 151, Pe 848 and Pe 841 *d*.

2. In this paper, seven species are described as new, namely, *Amoebotaenia fuhrmanni*, *A. pekinensis*, *Monopylidium guiarti*, *Choanotaenia joyeuxi*, *Haploparaxis sinenis*, *Fuhrmanniella clerci*, and *Gyrocoelia fausti*.

3. The present study indicates, to a certain extent, that the Chinese fauna of the avian cestodes is more or less related to that of the Ural, Australia, Egypt and Europe.

Pe 848 is an interesting tapeworm recorded from the liver of *Totanus calidris*. Owing to the poor preservation, the strobilae can not be examined, but its incomplete rostellar hooks, larger 0·0234 mm., and smaller 0·0216 mm. shown in Fig. 54, are characteristic.

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Legends to Figs. 47–53.

Figs. 47–53, *Gyrocoelia fausti* n.sp. (47) Rostellum enlarged. (48) Scolex, neck and portion o strobila showing beginning of genital organs. (49) Rostellar hooks. (50) Hooklets of cirrus. (51) Mature male segment. (52) Mature female segment. (53) Mature egg.

Lettering to figures: *An.* Anlage of genital organs; *Cp.* Cirrus pouch; *Ev.* Excretory vessels; *Gv.* Vitelline gland; *H.* Rostellar hooks; *N.* Neck; *O.* Ovary; *R.* Rostellum; *S.* Sucker; *Sg.* Shell gland; *T.* Testes; *U.* Uterus; *Vd.* Vas deferens.

ON SOME PARASITIC NEMATODES COLLECTED IN CHINA[1].

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(With 46 Figures in the Text.)

The following notes deal with nine species of parasitic nematodes from the Yangtze Valley and an additional one from North China. Of these ten species, one belongs to the super-family Rhabdiasoidea, three to Oxyuroidea, and six to Spiruroidea; three species have been previously described; therefore in these cases the writer gives only their measurements and a description of the particulars in which he found them to differ from the original description. Seven species *Rhabdias annulosa* n.sp., *Pingus sinensis* n.g. et n.sp. (Pingidae n.f.), *Omeia hoepplii* n.g. et n.sp., *Thelazia chungkingensis* n.sp., *Oxyspirura kaitingensis* n.sp., *Oxyspirura peipingensis* n.sp., *Oxyspirura tsingchengensis* n.sp., are new to science.

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Rhabdias annulosa n.sp. (Figs. 1–4).

Diagnosis. Rhabdias with a cup-shaped buccal cavity covered by a ring-like structure immediately behind the six small lips. Nearly related to *R. ophidia* Goodey 1924, and *R. fuscovenosa* (Railliet, 1899).

Host: *Zaocys dhumnades*, a snake.—*Location*: lung.—*Locality*: Nanking,

[1] Contribution from the Division of Parasitology, Department of Pathology, Peiping Union Medical College, Peiping, China.

China.—*Intensity of infection*: one out of one.—*Material*: nine specimens.—*Type specimens*: Helminth. Coll., Biological Laboratory, The Science Society of China, Nanking, China.

Measurements in mm. made on five specimens: body length 5·650–6·300, width 0·260–0·310; nerve ring to anterior end 0·146–0·162; excretory pore to anterior end 0·212–0·260; oesophageal length 0·310–0·320; oesophageal width: anterior portion 0·050–0·053, middle portion 0·044–0·049, posterior portion 0·062–0·068; vulva to anterior end 2·290–2·560; egg 0·031–0·037 × 0·063–0·068; tail 0·153–0·179.

The mouth (Figs. 1 and 2) is terminal and surrounded by six small lips. Each of the lateral lips bears an amphid and a lateral papilla in an arrangement similar to that described by Steiner (1924) for a larval Ascarid, *Agamascaris odontocephala*, and there is a sub-medial papilla on each of the four sub-medial lips. Immediately behind the lips there is a ring-like chitinous structure which surrounds the mouth opening like a diaphragm. The wall of the buccal cavity is cup-shaped. The oesophagus (Fig. 3) is club-shaped. The mid-intestine is brown, with a powerful muscular sphincter at its junction with the rectum. About five rectal glands (Fig. 4) are seen in the lateral view, three rather prominent and two smaller ones. The two cervical glands (Fig. 3) are large and have their nuclei near their posterior end. Their connection with the excretory pore lies at a short distance behind their anterior extremity. The nerve ring is situated at about the middle of the length of the oesophagus. The vulva is located anterior to the middle of the body, and its distance from the anterior end in proportion to the distance from the posterior end is 1:1·4. The arrangement of the two uteri and the ovaries is the one typical of the genus. The receptaculum seminis does not have a particularly well-developed wall and has no loop at its distal end. The eggs in the uteri near the vagina are in the morula stage.

Discussion. *Rhabdias annulosa* is nearly related to *R. fuscovenosa* and *R. ophidia*. The differences between *R. annulosa* and *R. fuscovenosa* are that *R. annulosa* has the above-described ring-like chitinous structure around the anterior part of the buccal cavity; furthermore the oesophagus and tail are longer in *R. annulosa*. The receptaculum seminis shows a different structure in the two species. The differences between *R. annulosa* and *R. ophidia* are in the absence of the ring-like chitinous structure around the anterior part of the buccal cavity in the latter, and in the fact that the buccal cavity in *R. ophidia* is funnel-shaped with straight (not curved) walls.

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Heterakis spumosa Schneider 1866 (Figs. 5 and 6).

Host: *Rhizomys* sp., Bamboo rat.—*Location*: small intestine and caecum.—*Locality*: Opien, Szechuan, China.—*Intensity of infection*: two out of three.—*Material*: seven males and thirty-eight females.—*Specimens*: Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking.

Measurements in mm. made on 5 ♂ *and* 5 ♀. **Male**: body length 8·400–10·200, width 0·470–0·500; nerve ring to anterior end 0·270–0·330; excretory pore to anterior end 0·420–0·460; oesophagus 0·650–0·740; spicules 0·313–0·430; sucker 0·098–0·115; tail 0·260–0·400.

Female: body length 11·650–12·300, width 0·480–0·530; nerve ring to anterior end 0·300–0·390; excretory pore to anterior end 0·430–0·490; oeso-

* Original paper not seen.

phagus 0·730–0·820; vulva to anterior end 5·700–6·100; egg 0·047–0·049 × 0·074–0·080; tail 0·730–0·920.

There are several slight differences between my material and *H. spumosa* as described by Lane. The oesophagus in my specimens is slightly shorter than in those examined by Lane. The two pairs of paracloacal papillae (Fig. 6) lie in an arrangement whereby one is cephalad and one caudad of the cloacal opening, instead of "one beside and one shortly cephalad of the cloacal opening." Moreover, instead of a pair of lateral head papillae, as noted by Lane, there is in my material one sub-medial papilla and an amphid in each of the sub-ventral lips. All sub-medial papillae have double nerve endings (Fig. 5).

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Cosmocercoides pulcher Wilkie 1930 (Figs. 7–10 and 45).

Host: *Bufo bufo japonica*, toad.—*Location*: rectum.—*Locality*: Hochow, Szechuan, China.—*Intensity of infection*: one out of one.—*Material*: seven males and nineteen females.—*Specimens*: Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking.

Measurements in mm. made on 2 ♂ *and* 5 ♀. **Male**: body length 7·00–7·600, width 0·41–0·500; pharynx 0·080; nerve ring to anterior end 0·440; excretory pore to anterior end 0·700; oesophagus (pharynx and oesophageal bulb included) 1·09–1·100; oesophageal bulb: length 0·14–0·160, width 0·13–0·168; spicules 0·31–0·320; gubernaculum 0·16–0·180; tail 0·23–0·270.

Female: body length 7·90–11·000, width 0·51–0·610; pharynx 0·11–0·130; nerve ring to anterior end 0·45–0·550; excretory pore to anterior end 0·74–0·880; oesophagus (pharynx and oesophageal bulb included) 1·22–1·450; oesophageal bulb: length 0·15–0·210, width 0·16–0·200; vulva to posterior end 3·34–5·040; egg 0·038–0·045 × 0·06–0·070; tail 0·35–0·520.

The measurements of my specimens agree entirely with those given by Wilkie except for a very slight difference consisting of the fact that in my specimens spicules and gubernaculum are somewhat longer than those of Wilkie's material. In addition, the number and arrangement of papillae in both sexes, as given below, are a little different from those as described by Wilkie.

In my specimens at the very extremity of the anterior end (Figs. 7 and 9) there are two sub-medial papillae in the dorsal lip, and one sub-medial papilla and an amphid in each of the sub-ventral lips. Each papilla bears two nerve endings which do not appear at the same level when seen in frontal view. There are in both sexes four rows (two ventral and two dorsal) of numerous, small papillae situated throughout the whole body length (Fig. 7). In the tail of my male specimens (Figs. 8 and 10) two ventral rows of the complex papillae surrounded by cuticular tubercles are also present; this corresponds

to the findings of Wilkie. Of them, the second pair (counted from the posterior end) and its additional lateral pair, however, are situated postcloacally in my specimens, instead of precloacally as described by Wilkie. Anteriorward, they become much smaller at their tenth pair and lose their cuticular tubercles from the eleventh pair on. Becoming smaller and smaller they at last join respectively each row of small lateral papillae, which are situated rather closely lateral to each row of the complex papillae, to form two ventral rows of body papillae. Lateral to the most posterior pair of the complex papillae, there is in my specimens a pair of small lateral papillae, a fact which is not noted in Wilkie's description. Posterior to the most posterior pair of the complex papillae, there is a very prominent pair of ventral papillae, which, most probably, corresponds to "a large ventral pair" as given by Wilkie. Between these prominent ventral papillae and the most posterior pair of the complex papillae, there are three pairs of small ventral papillae (the posterior two pairs are situated more closely) and one pair of small lateral papillae instead of only "a small ventral pair" as given by Wilkie. Posterior to the very prominent ventral papillae, there is at first one pair of small ventral papillae, then one pair of small lateral papillae, and then one pair of small ventral papillae, sometimes asymmetrically arranged, and, most posteriorly, again a rather prominent pair of ventral papillae, sometimes also asymmetrically arranged, instead of "two small lateral pairs, two large lateral pairs and a small ventral pair having the form of a double papilla" as described by Wilkie. Concerning the dorsal papillae of the caudal end, Wilkie's one pair of large dorsal papillae situated at the same level with the above-mentioned very prominent pair of ventral caudal papillae is also present in my specimens. There have been found, however, posterior to Wilkie's only pair of dorsal papillae, three pairs (two small and one also rather prominent) of additional dorsal papillae in my specimens; anterior to Wilkie's only pair of dorsal papillae, my specimens also have numerous small pairs of dorsal papillae which are in the line of the two rows of the dorsal body papillae.

In the tail of the female, no caudal papillae are described by Wilkie. I find, however, in the tail of my specimens (Fig. 45), four pairs of ventral papillae, one pair of lateral papillae and four pair of dorsal papillae. The pre-anal papillae of the female are actually in the line of the four rows, two dorsal and two ventral, of body papillae, as was mentioned before.

The two homogeneous transverse zones of the oesophagus, as described by Steiner (1924) in a related form, *Cosmocercella haberi* Steiner 1924, are also present in the specimens of the present species.

Though my specimens differ so much, as mentioned above, from Wilkie's description of the type specimen, I am however still of the opinion that my specimens most probably belong to the species *C. pulcher*, because both are oriental forms, both come from nearly related hosts (exact scientific name of the host of the type specimen lacking) and, moreover, the measurements of my specimens agree entirely with those of Wilkie's type specimen. I prefer

not to give a new name to my material before I have had an opportunity to examine the type specimen.

C. pulcher is closely related to *Oxysomatium variabilis* Harwood 1930, which also possesses large complex caudal papillae with a ring of cuticular tubercles. If this character is regarded as of generic value, *Oxysomatium variabilis* must be put into Wilkie's genus *Cosmocercoides*. I consider Wilkie justified in establishing a new genus, *Cosmocercoides*, to separate species provided with these characteristic complex caudal papillae just as the genera *Cosmocerca* and *Cosmocercella* have been established on account of the presence of plectanes. The peculiar papillae of *Cosmocercoides* as found in three different species (*Oxysomatium variabilis*, *Cosmocercoides pulcher* and *Cosmocercoides tridens*) are in my opinion of more than specific value, therefore, I do not agree with Harwood in his suggestion.

It must be left for further investigation to determine whether *Cosmocerca*, *Cosmocercella* and *Cosmocercoides* should remain separated.

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Wilkie, J. S. (1930). Some parasitic nematodes from Japanese amphibia. *Ann. Mag. Nat. Hist.* Ser. 10, **6**, 607–10.

Spinicauda japonica Wilkie 1930 (Figs. 11–14 and 21).

Host: *Bufo bufo japonica*, toad.—*Location*: rectum.—*Locality*: Hochow, Szechuan, China.—*Intensity of infection*: one out of one.—*Material*: six males and thirteen females.—*Specimens*: Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking.

Measurements in mm. made on 5 ♂ *and* 3 ♀. **Male**: body length 5·630–6·150, width 0·300–0·350; nerve ring to anterior end 0·280–0·330; excretory pore to anterior end 0·450–0·510; pharynx 0·070–0·080; oesophagus (pharynx and oesophageal bulb included) 0·870–0·940; oesophageal bulb: length 0·160–0·200, width 0·155–0·190; spicules: left 0·570–0·650, right 0·600–0·690; gubernaculum 0·020; tail 0·220–0·270.

Female: body length 6·350–6·780, width 0·252–0·350; nerve ring to anterior end 0·290–0·320; excretory pore to anterior end 0·450–0·490; pharynx 0·080–0·090; oesophagus (pharynx and oesophageal bulb included) 0·960–1·050; oesophageal bulb: length 0·160–0·210, width 0·150–0·170; vulva to anterior end 2·480–2·630; egg 0·048–0·058 × 0·078–0·083; tail 0·358–0·380.

The measurements of my specimens and all characteristics, with the exception of a few minor ones mentioned below, correspond very well with those given by Wilkie.

In my material, the anterior end (Figs. 11 and 12) is rather interesting. Besides the sub-medial papillae in the dorsal lip and one sub-medial papilla

and an amphid in each of the sub-ventral lips, there are also one lateral papilla in each ventral lip near the amphid and two inner labial papillae in each of the three lips as described by Hoeppli (1925) in *Ascaroidea*, by Hsü and Hoeppli (1931) in a species of *Spiruroidea* (*Acuaria longicaudata*), and by Steiner (1924) in another species of *Oxyuroidea* (*Cosmocercella haberi*). There are two cuticular wings and one inner cuticular tooth in each of the three lips. Moreover in my material the oesophagus is slightly shorter, the excretory pore slightly more anterior, and the gubernaculum of the male and the tail of the female rather shorter than those of Wilkie's specimens. With regard to the caudal papillae of the male (Figs. 13 and 14), in my specimens the three pairs of post-anal papillae are situated as was described by Wilkie. In addition to the two pairs of adanal papillae (one very large and the other small) described by Wilkie, there are in my specimens three more pairs of adanal papillae, two anterior to and one posterior to the cloaca. Concerning the pre-anal papillae, my specimens also show a slight difference from Wilkie's. There are two very prominent pairs of lateral papillae near the level of the pre-anal sucker. Occasionally one or two pairs of inconstant papillae of variable size appear anterior or lateral to the above-mentioned two pairs of very prominent papillae. Posterior to these very prominent papillae there is a pair of lateral papillae of variable size. There are, moreover, two small pairs of ventral papillae situated lateral to the pre-anal sucker. Anterior to the pre-anal sucker there are about five small pairs of ventral papillae. As the pre-anal papillae are not very distinct in Wilkie's drawing, it is very difficult for me to identify his eight pairs of pre-anal papillae in my specimens. No papillae were mentioned by Wilkie in connection with the tail of the female. In the tail (Fig. 21) of my female specimens, however, two pairs of lateral papillae and one pair of ventral papillae are seen. Moreover, about five pairs of dorsal body papillae are seen in my specimens, of which the most posterior pair is situated at about the level of the cloaca.

The above-mentioned differences between Wilkie's type specimens and my material seem somewhat beyond the range of variation. But as both are oriental forms and both come from nearly related hosts (exact scientific name of the host of type specimen lacking), and certain variations of caudal papillae do occur in my specimens, as mentioned above, I am of the opinion that it is better to place the present specimens under the name *S. japonica*. I prefer not to give a new name to my material before I have had an opportunity to examine the type specimen.

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WILKIE, J. S. (1930). Some parasite nematodes from Japanese amphibia. *Ann. Mag. Nat. Hist.* Ser. 10, **6**, 612–13.

Pingidae n.f.

Family diagnosis. Spiruroidea: mouth without lips; vestibule absent; oesophagus long and cylindrical, and divided into a short anterior muscular portion, and a long glandular part; lateral flanges present. *Male*: caudal alae

well-developed and supported by four pedunculated pre-anal papillae; muscular pre-anal sucker present. *Female*: vulva behind the middle of the body. Oviparous. Parasites of the caecum of freshwater fishes.

Family type and only known genus *Pingus* n.g.

Discussion. Pingidae n.f. is related to Cucullanidae on account of the presence of the pre-anal muscular sucker and also related to Spiruridae on account of the absence of lips and the presence of the four large pedunculated pre-anal papillae.

I have a great pleasure in naming this new family in honour of Dr C. Ping, Director of the Biological Laboratory of the Science Society of China, Nanking, from whom I received my first impetus towards the study of zoological science.

Pingus n.g.

Generic diagnosis. Pingidae: mouth opening triangular; head with two amphids and four sub-medial papillae; excretory pore near the posterior extremity of the oesophagus. *Male*: tail pointed, spicules equal and similar; gubernaculum present; a single, papilla-like glandular opening between the most posterior two pairs of the pedunculated pre-anal papillae. *Female*: vulva at the region of about one-third of the body length from the posterior extremity. Two uterine tubes, oviparous, eggs with smooth shell and unsegmented granular contents at deposition.

Genotype and only known species, *Pingus sinensis* n.sp.

Pingus sinensis n.sp. (Figs. 15–20 and 46).

Specific diagnosis. Pingus with two pairs of pedunculated adanal papillae and five pairs of pedunculated post-anal papillae in the male, and a rather prominent anterior lip of the vulva.

Host: *Ophicephalus argus*, fish.—*Location*: caecum.—*Locality*: Nanking and Peiping.—*Intensity of infection*: eight out of ten.—*Material*: numerous.

Type specimens: *Types*, Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking. *Cotypes*, Division of Parasitology, Peiping Union Medical College, Peiping.

Measurements in mm. made on 5 ♂ *and* 5 ♀. **Male**: body length 4·000–4·600, width (excluding alae) 0·110–0·140; nerve ring to anterior end 0·160–0·178; excretory pore to anterior end 0·425–0·480; oesophagus: muscular 0·168–0·170, glandular 0·275–0·360; spicules 0·050–0·540; tail 0·122–0·140.

Female: body length 4·140–5·100, width (excluding alae) 0·126–0·138; nerve ring to anterior end 0·165–0·206; excretory pore to anterior end 0·435–0·556; oesophagus: muscular 0·165–0·206, glandular 0·290–0·380; vulva to posterior end 1·380–2·000; egg 0·030–0·038 × 0·063–0·080; tail 0·190–0·260.

The cuticle is smooth. The lateral flanges (Figs. 15 and 16) are broadest in the anterior region and gradually narrow caudad. At the anterior extremity the sub-cuticular tissue curves outwards in forming the connection with the

anterior end of the lateral flanges (Fig. 15). The mouth opening (Figs. 15–17) is small, triangular, and without lips. There is no vestibule. The anterior end bears two amphids and four sub-medial papillae, which have double nerve endings and a prominent cuticular thickening. The oesophagus (Fig. 17) is divided into a muscular and glandular portion. In the most anterior region of the former there is a special muscular portion with a length of about 24 μ (Figs. 15 and 17). The nerve ring (Fig. 17) is situated just at the junction of the muscular and glandular portions of the oesophagus. The excretory pore (Fig. 17) is situated at the level of the posterior end of the oesophagus.

Male. The tail (Figs. 18 and 19) is pointed, spirally coiled, and carrying well-developed caudal alae. A muscular precloacal sucker is seen. The spicules are equal and similar; they are rather short and with a somewhat pointed end. There are four pairs of pedunculated pre-anal papillae with nearly the same distance between each one and the next, of which the most anterior pair is situated just at the level anterior to the muscular sucker. Between the most posterior two pairs there is a single, papilla-like glandular opening. Two pairs of slender, pedunculated adanal papillae are present. There are five pairs of prominent, pedunculated post-anal papillae of which the most anterior pair and the second pair counted from the posterior end are ventral and more prominent than the ones which are situated laterally.

Female. The vulva (Fig. 20), which has a rather prominent anterior lip, is situated behind the middle of the body about one-third of the length of the worm from the posterior extremity. The vagina is broad and strongly muscularised, and, after running anteriorly about 70 μ, divides itself into two broad uterine tubes: an anterior and a posterior one. In the uterine tubes there are only a few eggs (Fig. 20) present. They are big, oblong, and with a somewhat thick and smooth shell and unsegmentated granular contents. The tail (Fig. 46) is slender, straight, and pointed. The ovary extends almost to the posterior extremity.

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Omeia n.g.

Generic diagnosis. Thelaziidae: mouth with six dentigerously ridged small lips, followed by a chitinous buccal capsule which is triangular in cross section; two amphids, four sub-medial papillae with double nerve endings, and six labial papillae; oesophagus long and muscular throughout; intestinal caecum present. *Male*: tail pointed, without caudal alae; a large number of pre-anal papillae and four pairs of post-anal papillae; spicules similar and sub-equal; gubernaculum present. *Female*: tail pointed; vulva about in the middle of the body; two uterine tubes, oviparous, eggs with a thick smooth shell and

unsegmented granular contents at deposition. Parasites of the digestive tract of frogs.

Genotype and only known species: *Omeia hoepplii* n.sp.

Genus named after Mount Omei in Szechuan.

Omeia hoepplii n.sp. (Figs. 22–27).

Specific diagnosis: with the characters of the genus.

Host: *Rana tibetana*, frog.—*Location*: stomach and intestine.—*Locality*: Mts Omei and Tsingcheng, Szechuan, China.—*Intensity of infection*: two out of eighteen.—*Material*: eight males and nine females.—*Type specimens*: Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking.

Measurements in mm. made of 4 ♂ *and* 4 ♀. **Male**: body length 23·300–33·250, width 0·510–0·630; nerve ring to anterior end 0·520–0·610; excretory pore to anterior end 0·570–0·670; oesophagus 2·260–2·600; intestinal caecum 1·080–1·350; spicules: left 0·500–0·650, right 0·461–0·600; gubernaculum 0·130–0·200; tail 0·200–0·270.

Female: body length 32·800–58·200, width 0·580–0·880; nerve ring to anterior end 0·560–0·750; excretory pore to anterior end 0·620–0·820; oesophagus 2·750–3·680; intestinal caecum 1·330–1·620; vulva to posterior end 16·580–24·850; egg 0·054 × 0·037; tail 0·250–0·330.

The cuticle is finely striated. There are six small lips with dentigerous ridges (Figs. 22–24). Two amphids, four prominent sub-medial papillae with double nerve endings, and six labial papillae are seen. The mouth opening leads into a thick-walled buccal capsule which appears triangular from the frontal view. Oesophagus (Fig. 25) long, slender and muscular throughout. A long intestinal caecum is present, originating from the ventral side of the most anterior part of the intestine.

Male. The tail (Fig. 26) is very short, pointed and bent ventrally. The spicules are similar and sub-equal. They both have a ventral groove and a blunt tip. There is a large, triangular gubernaculum. The number of ventral pre-anal papillae is variable, ranging from nine to fifteen, and the distances between them are also not constant in different specimens. There are four pairs of ventral post-anal papillae with the distances between each two more or less the same throughout.

Female. The vulva is situated slightly anterior to, slightly posterior to, or at the middle of the body length. There are no prominent lips at its opening. The vagina leads about 680 μ long cephalad, then divides into two uterine branches, which run cephalad and caudad respectively. The eggs are nearly spherical, with a smooth shell of about 2–3 μ in thickness, and unsegmented granular contents at deposition. The tail (Fig. 27) is pointed and bent slightly ventrally.

Discussion. All the characteristics of the present specimens agree very well with those of the family Thelaziidae Railliet 1916, except that the oesophagus of the present specimens does not consist of two parts. However, in

the same family, *Thelazia chungkingensis* n.sp., *Oxyspirura kaitingensis* n.sp., *Oxyspirura peipingensis* n.sp., and *Oxyspirura tsingchengensis* n.sp., described in the present paper, and *Thylaconema sigmura* Chandler 1929 also have their oesophagus muscular throughout, without either two different muscular parts or a muscular and a glandular portion.

As there is no genus of the family Thelaziidae with an intestinal caecum, it is certainly justifiable to place the present specimen, on account of the presence of the additional character, in a new genus.

The species is named in honour of Dr R. Hoeppli, Professor of Parasitology, Peiping Union Medical College, Peiping, from whom I have been receiving my impetus toward the study of Nematology.

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Thelazia chungkingensis n.sp. (Figs. 28–31 and 44).

Diagnosis. Thelazia nearly related to *T. papillosa* (Molin, 1860) Railliet and Henry 1910, and *T. anolabiata* (Molin, 1860) Railliet and Henry 1910, differentiated from the former by the absence of the spines in its cervical region and its shorter body length, and differentiated from the latter by the shorter body length.

Host: *Chibia hottentotta brevirostris*, the hair-crested drango (bird).—*Location*: under nictitating membrane.—*Locality*: Chungking, Szechuan, China.—*Intensity of infection*: one out of one.—*Material*: three males and two females.—*Type specimens*: Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking.

Measurements in mm. made of 3 ♂ *and* 2 ♀. **Male**: body length 6·880–8·440, width 0·290–0·350; buccal cavity: depth 0·037–0·038, width 0·043–0·045; nerve ring to anterior end 0·230–0·258; oesophagus 0·440–0·520; spicules: left (in body length of 6·88 mm.) 0·900, right (in body length of 6·88 mm.) 0·122; tail 0·105–0·117.

Female: body length 8·850–9·830, width 0·430–0·438; buccal cavity: depth 0·041–0·045, width 0·048–0·051; nerve ring to anterior end 0·225–0·250; oesophagus 0·460–0·550; vulva to anterior end 0·440–0·490; egg 0·021–0·022 × 0·035–0·036; tail 0·093–0·110.

The cuticle is striated, with 12 μ distance between two striae in the region of the posterior end of the oesophagus. Lips (Figs. 28 and 29) are absent. The mouth opening is oblong and is surrounded by six festoons. There are two amphids and four sub-medial papillae. A wide chitinous buccal cavity is present. The oesophagus is muscular throughout and does not show two

different muscular portions, as Railliet stated to be the case in his definition of the family characters of Thelaziidae (1916).

Male. The tail (Figs. 30 and 31) is slightly curved towards the ventral side and has a very blunt tip. The spicules are very dissimilar and unequal. The left one is long, slender, and alated at its tip; whereas the right one is short, strong, and also alated at its blunt tip. Two pairs of post-anal ventral papillae, at variable distances from each other, are seen. There are from six to eight ventral pairs of pre-anal papillae, which also show considerable variation in their distances from one another.

Female. The vulva is situated almost at the level of the posterior end of the oesophagus. The cuticle is somewhat thickened around the vulva opening, but there are no distinct lips. The eggs are oblong and either with contents in morula stage or with a developed embryo inside. The tail (Fig. 44) is very blunt and slightly curved ventrally.

Discussion. Up to the present time several species of *Thelazia* have remained very incompletely described, this being especially true for the species *T. anolabiata* and *T. papillosa*, both of which are similar to *T. chungkingensis*. The description of *T. anolobiata* really gives nothing except the body length of the female worms; based on this very uncomplete description it would not be difficult to regard various different species of this genus as belonging to the species *T. anolobiata*. Though the female body length of my specimens agrees with the minimum female body length of *T. anolobiata*, the body length of my larger female specimens with mature eggs containing larvae does not however go beyond 9·83 mm., as compared with 17 mm., the maximum female body length of *T. anolabiata*. I am of the opinion that it is better to regard my material as a new species rather than to complicate further the unsatisfactorily described species *T. anolabiata*. With regard to *T. papillosa*, the two characteristics of my specimens—the absence of spines in the cervical region and the shorter body length of female specimens—justify the separation of the present specimens from the old species.

The new species is named after the city of Chungking in Szechuan.

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Oxyspirura kaitingensis n.sp. (Figs. 32–36).

Diagnosis. Oxyspirura, nearly related to *O. anthochaerae* (Johnston, 1912) Johnston 1912, differentiated by the presence of head cuticular expansions in both sexes, shorter body length, shorter tail length, and the presence of caudal papillae in the male.

Host: *Lanius tigrinus*, the thick-billed shrike (bird).—*Location*: under the nictitating membrane.—*Locality*: Kaiting, Szechuan, China.—*Intensity of infection*: one out of one.—*Material*: two males and two females.—*Type specimens*: Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking.

Measurements in mm. made on 2 ♂ *and* 2 ♀. **Male**: body length 5·890–6·190, width 0·252–0·253; buccal capsule: depth 0·021–0·022, width 0·017–0·018; nerve ring to anterior end 0·127–0·135; excretory pore to anterior end 0·230–0·237; oesophagus 0·577–0·590; spicules: left 0·300–0·410, right 0·140–0·148; tail 0·130.

Female: body width 0·330; oesophagus (from posterior end) to posterior end of the body (from the specimen with the tail length of 0·2 mm.) 7·430; vulva to posterior end 0·328–0·385; egg 0·019–0·022 × 0·033; tail 0·174–0·200.

The cuticle is very finely striated. In the head region of both sexes, there are six cuticular expansions (Figs. 32 and 33), of which the two smaller ones are laterally situated, and the four larger ones, sub-medially situated; all of them extend from the level of the buccal capsule posteriorly to that of the nerve ring. There are six inconspicuous lips, with central incision, surrounding the mouth opening. There are two amphids, four rather prominent and four small sub-medial head papillae. The mouth-opening leads into a wide, buccal cavity with a thickened wall. The oesophagus is muscular throughout and is not divided into two portions as was stated to be the case by Railliet in his definition of the family characters of Thelaziidae (1916). There is a cuticular thickening at the opening of the excretory pore.

Male. The tail (Figs. 34 and 36) is pointed and coiled ventrally. The spicules are very dissimilar and unequal. The left one is longer, alated, bluntly pointed, and with a sub-ventral groove. The right one is short, stout, and with an obtuse hollow end. There are two very long retractor muscles connected with the root of each of the spicules. There are three pairs of irregularly arranged pre-anal papillae and four pairs of post-anal papillae, of which the more anterior three pairs are irregularly situated near the cloaca and the most posterior pair is situated about midway the length of the tail.

Female. The vulva (Fig. 35) is situated at a short distance before the anus and leads into a short strongly muscular vagina which divides into two uterine tubes after a length of 270 μ. The eggs near the vagina are oval and with an already developed larva inside. The tail (Fig. 35) is pointed, but not very sharply, and slightly bent dorsally.

Discussion. From the *diagnosis* of this new species, as given above, there is no doubt that the new species cannot be the *O. anthochaerae* described by Johnston. However I would like to point out that as the type specimens of *O. anthochaerae* described by Johnston were in bad condition, owing to drying, as Johnston himself stated, it is not impossible that the exactness of his description suffered from the fact that the material was poorly preserved. This possibility may be of particular importance in connection with the reported absence of caudal papillae in the male. If a re-examination of the same species from *Anthochaera carunculata* should show the presence of caudal papillae in the male and the presence of the head cuticular expansion in both sexes, and also a shorter body length and tail length in the male, as is noted in my description, the name given by me will simply become a synonym and will not create any complications with regard to the systematics of *Oxyspirura*.

O. kaitingensis is named after the city of Kaiting in Szechuan.

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Oxyspirura peipingensis n.sp. (Figs. 37–39).

Diagnosis. Oxyspirura nearly related to *O. sygmoidea* (Molin, 1860) Stossich 1897, and *O. siamensis* (Linstow, 1903) Ransom 1904, differentiated from the former by the different number and arrangement of caudal papillae, and from the latter by the different position of the excretory pore and the different number of caudal papillae.

Host: *Planesticus naumanni*, red-tailed thrush (bird).—*Location*: under

* Original paper not seen.

the nictitating membrane.—*Locality*: Peiping, China.—*Intensity of infection*: one out of one.—*Material*: two males and two females.—*Type specimens*: Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking.

Measurements in mm. made on 2 ♂ *and* 2 ♀. **Male**: body length 7·270–9·700, width 0·260–0·270; buccal capsule: depth 0·018–0·020, width 0·021–0·022; nerve ring to anterior end 0·142–0·182; excretory pore to anterior end 0·230–0·290; oesophagus 0·710–0·900; spicules: left 0·408–0·510, right 0·180–0·225; tail 0·255–0·280.

Female: body length 12·900, width 0·420; buccal capsule: depth 0·020–0·022, width 0·025–0·027; nerve ring to anterior end 0·163; excretory pore to anterior end 0·230–0·280; oesophagus 0·970–0·980; vulva to posterior end 0·570–0·620; egg 0·030 × 0·038; tail 0·315–0·355.

The cuticle is finely striated. The cuticular expansions are absent in both sexes. The mouth opening (Figs. 37 and 38) is circular and leads into a buccal cavity which shows a rather prominent bulge in its middle portion. There are two amphids and four very prominent and four other rather small submedial head papillae. In addition to these, there are six small inner papillae surrounding the mouth opening. The oesophagus is muscular throughout. No cuticular prominence is seen at the opening of the excretory pore.

Male. The tail (Fig. 39) is pointed and coiled ventrally about one and a half times. The spicules are very dissimilar and unequal. The left one is slender, with a pointed tip and a groove on its ventral side; the right one is stout, navicular, with an obtuse tip and also with a ventral groove. Neither of them is alated. There are three pairs of very prominent, closely situated, pre-anal papillae and also three pairs of very prominent post-anal papillae, of which the anterior two pairs are situated very close to the cloaca and the most posterior pair is at a marked distance from the anterior two pairs.

Female. The vulva is situated near the anus and leads into a short muscular vagina from which the two uterine tubes take their origin after a length of about 0·4 mm. The eggs near the vagina are oval, with a somewhat thick and smooth egg shell, and with a developed larva inside. The tail is pointed, with a pair of lateral papillae situated about 132 μ from the tip.

Discussion. Although the general measurements of the present specimens are more or less similar to *O. sygmoidea* (Molin, 1860) Stossich 1897, and *O. siamensis* (Linstow, 1903) Ransom 1904, the number and arrangement of both the pre-anal and post-anal papillae are quite different. These are so definite and prominent in the present specimens that it seems impossible that former authors could have described the present species as possessing four pairs of pre-anal papillae and apparently no post-anal papillae (*O. sygmoidea*) or about 28 pairs of pre-anal papillae and also no post-anal papillae (*O. siamensis*). The present material has therefore to be regarded as belonging to a new species of *Oxyspirura*.

O. peipingensis is named after the city of Peiping, formerly the capital of China.

Acknowledgment. The specimens of the new species are collected and sent to the writer for study by Professors Shisan C. Chen and T. H. Shaw of Tsing Hua University, Peiping, China; to both of them the writer wishes to express his great indebtedness.

REFERENCE.

See *O. kaitingensis* n.sp.

Oxyspirura tsingchengensis n.sp. (Figs. 40–43).

Diagnosis. Oxyspirura nearly related to *O. mansoni* (Cobbold, 1879) Ransom 1904, and *O. parvovum* Sweet 1919, differentiated from both of them by its shorter body length and its lesser difference of length between the two unequal spicules. The undulate shape of the long spicule is also characteristic of *O. tsingchengensis.*

Host: *Microscelis leucocephalus*, bird.—*Location*: under the nictitating membrane.—*Locality*: Mt Tsingcheng, Szechuan, China.—*Intensity of infection*: one out of one.—*Material*: seven males and four females.—*Type specimens*: Helminth. Coll., Biol. Lab., Sci. Soc. of China, Nanking.

Measurements in mm. made on 5 ♂ *and* 4 ♀. **Male**: body length 7·770–9·100, width 0·240–0·280; depth of anterior buccal cavity 0·012–0·018; posterior buccal cavity: depth 0·024–0·038, width 0·012–0·017; nerve ring to anterior end 0·185–0·230; oesophagus 0·930–1·080; spicules: left 0·200–0·256, right 2·060–2·250; tail 0·300–0·330.

Female: body length 9·370–11·700, width 0·300–0·400; depth of anterior buccal cavity 0·018–0·025; posterior buccal cavity: depth 0·027–0·032, width 0·012–0·017; nerve ring to anterior end 0·193–0·233; oesophagus 0·010–1·230; vulva to posterior end 0·670–0·850; egg (embryonated) 0·027–0·028 × 0·040–0·047; tail 0·220–0·306.

The cuticle is smooth. There are no cephalic membranous expansions in either sex. The mouth opening (Figs. 40 and 41) is hexagonal and leads into a well-developed buccal cavity. The latter is divided by a chitinous projection into a wide, short and, from the frontal view, hexagonal anterior part; and a deep, narrow and, from the frontal view, triangular posterior part. There are two amphids and four prominent sub-medial papillae. In addition to these there are six other small papillae near the mouth opening, two lateral and four sub-medial. The oesophagus is muscular throughout and is not divided into two portions as was stated to be the case by Railliet in his definition of the family characters of Thelaziidae (1916).

Male. The tail (Fig. 42) is curved towards the ventral side and has a pointed tip. The spicules are very dissimilar and unequal. The left one is short, strong, and alated at its blunt tip; whereas, the right one is long, slender, undulate in its course, and also alated at its round tip. The spicule sheath of both is very distinct. There are three pairs of post-anal papillae: two pairs of rather prominent ventral papillae just behind the cloaca and one pair of small, lateral papillae near the tip. There are three pairs of ventral

pre-anal papillae situated just anterior to the cloaca, the distance between the most anterior pair and middle pair is comparatively greater than that between the last pair and the middle pair. One out of seven of my specimens, however, shows a slight variation: there are, instead of three pre-anal papillae on each side, five on its left side and four on its right side.

Female. The vulva (Fig. 43) is situated near the anus without a prominent cuticular thickening around its opening. The eggs are oblong, either with contents in morula stage or with a developed larva inside. The tail (Fig. 43) is pointed and bears a pair of sub-ventral papillae near its tip.

Discussion. Besides the characteristics of the new species, as given above, there are still some more points which should be mentioned here. The presence of six small papillae surrounding the hexagonal mouth opening of the new species may be regarded as a differentiating character with regard to *O. mansoni*. As there is no good description concerning the head papillae in *O. parvovum*, I dare not say whether this also holds true concerning the latter. The number and arrangement of the caudal papillae of the new species seem rather to agree with that of *O. parvovum*, except for the most posterior pair of post-anal papillae near the tip of the tail of the male and the other pair at the tip of the tail of the female, which seem to be absent in *O. parvovum*. In my opinion it is not improbable that they may also be found in *O. parvovum* on re-examination. The buccal cavity of the new species also shows its close similarity with *O. parvovum*, though a second chitinous projection in the buccal cavity is not found in the new species. In my opinion *O. tsingchengensis* is more nearly related to *O. parvovum* than to *O. mansoni*.

O. tsingchengensis is named after Mt Tsingcheng in Szechuan.

REFERENCE.

See *Oxyspirura kaitingensis* n.sp.

Legends to Figs. 1–8.

Rhabdias annulosa n.sp. Figs. 1–4.

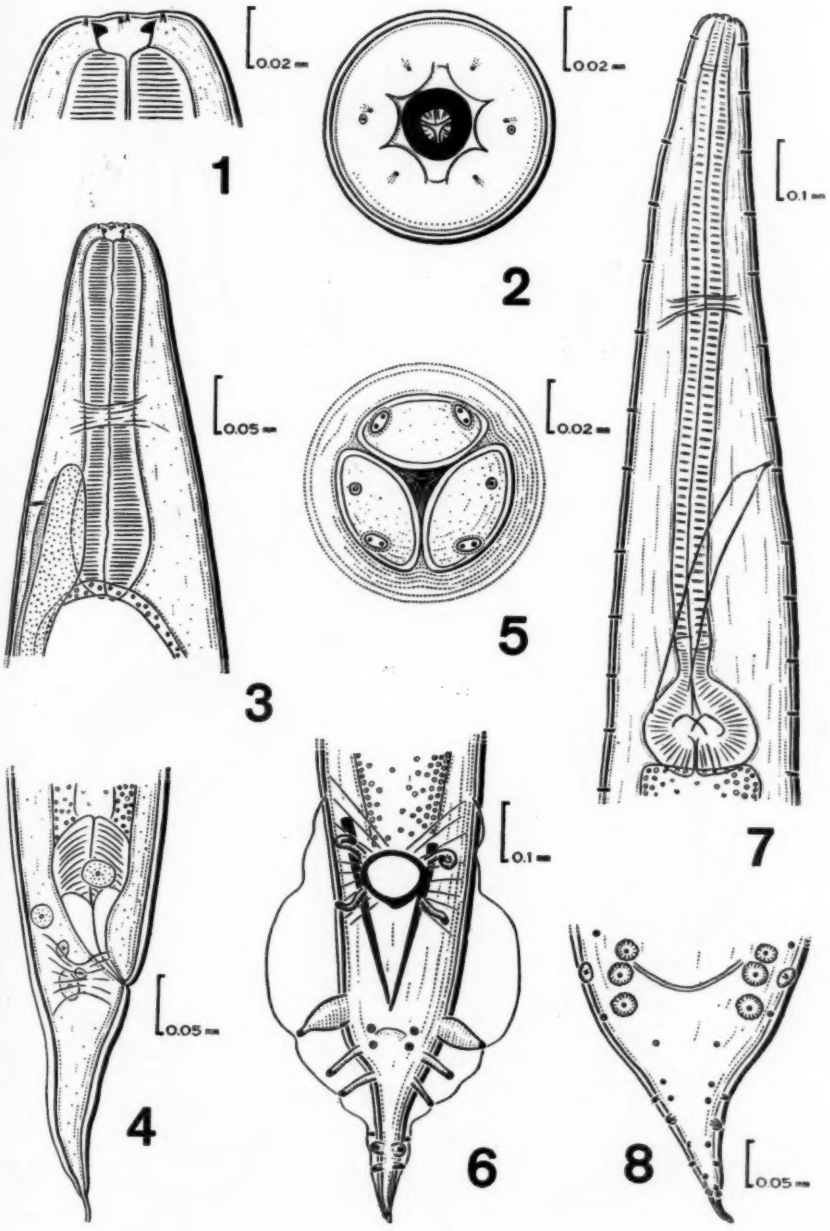
Fig. 1. Head, lateral view
Fig. 2. Head, frontal view.
Fig. 3. Anterior end, lateral view.
Fig. 4. Posterior end, lateral view.

Heterakis spumosa Schneider 1866. Figs. 5 and 6.

Fig. 5. Head, frontal view.
Fig. 6. Male, posterior end, ventral view.

Cosmocercoides pulcher Wilkie 1930. Figs. 7 and 8.

Fig. 7. Anterior end, lateral view.
Fig. 8. Male, posterior end, ventral view.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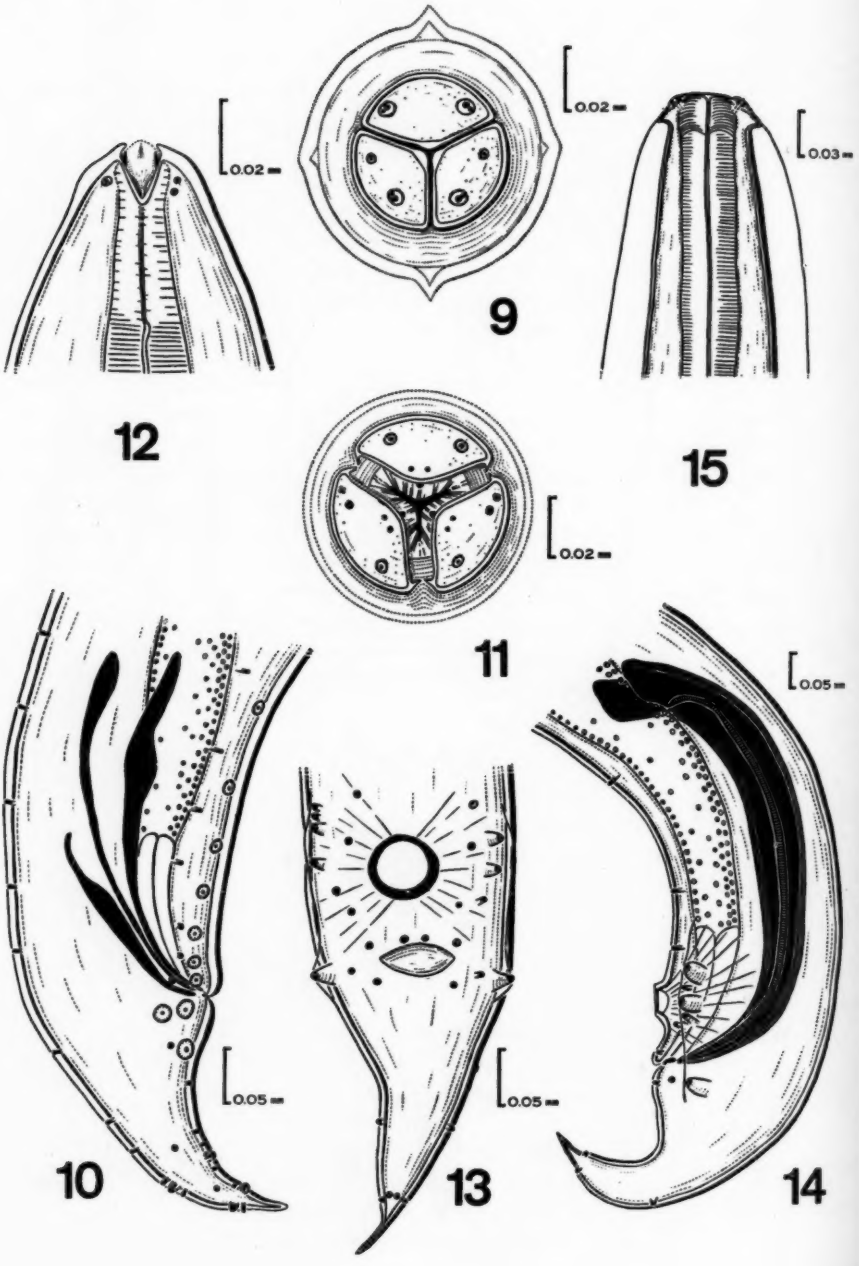
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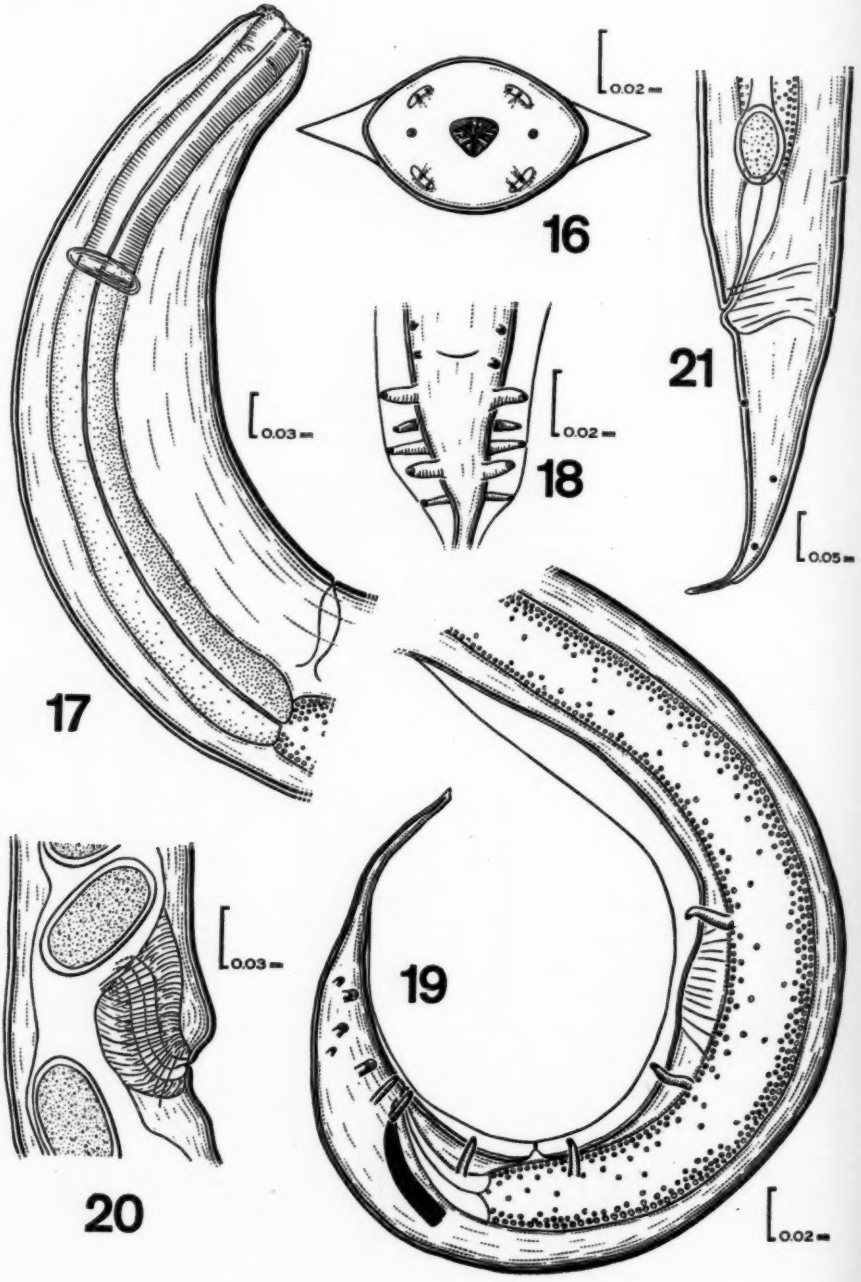
Legends to Figs. 9–15.

Cosmocercoides pulcher Wilkie 1930. Figs. 9 and 10.

Fig. 9. Head, frontal view.
Fig. 10. Male, posterior end, lateral view.

Spinicauda japonica Wilkie 1930. Figs. 11–14.

Fig. 11. Head, frontal view.
Fig. 12. Head, sub-dorsal view.
Fig. 13. Male, posterior end, ventral view.
Fig. 14. Male, posterior end, lateral view.
Fig. 15. *Pingus sinensis* n.g. et n.sp. Head, dorso-ventral view.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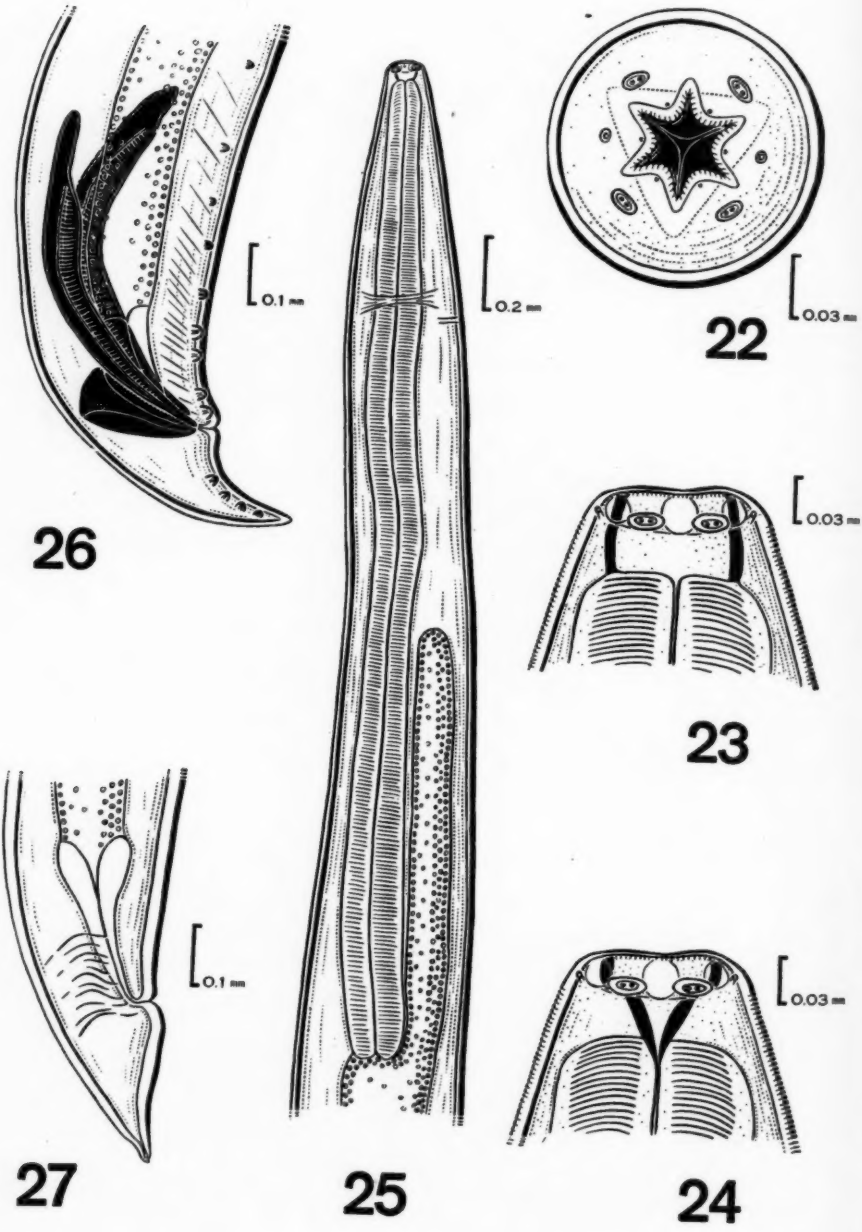
Pingus sinensis n.g. et n.sp. Figs. 16–20.

Fig. 16. Head, frontal view.
Fig. 17. Anterior end, lateral view.
Fig. 18. Male, posterior end, ventral view.
Fig. 19. Male, posterior end, lateral view.
Fig. 20. Female, vulva and eggs.
Fig. 21. *Spinicauda japonica* Wilkie 1930. Female, posterior end, lateral view.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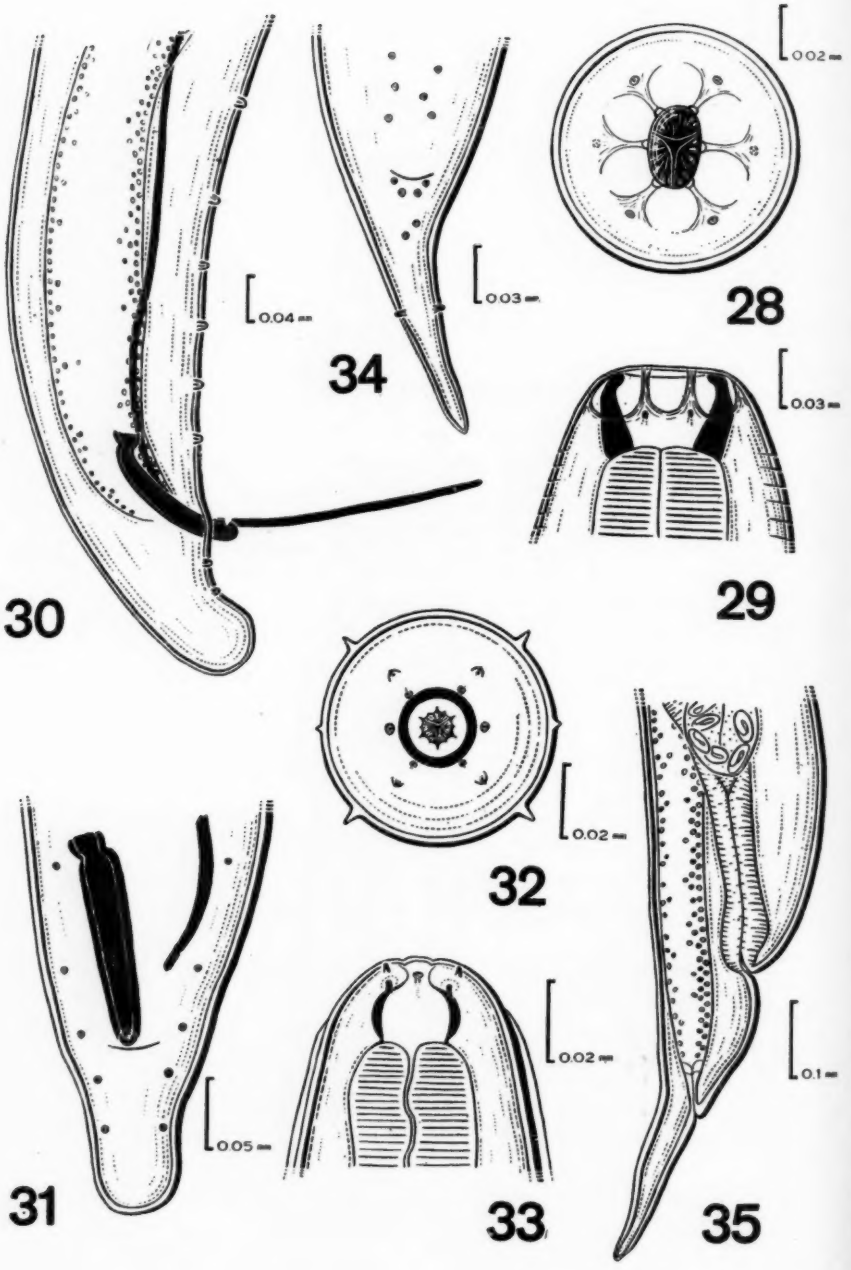
Omeia hoepplii n.g. et n.sp. Figs. 22–27.

Fig. 22. Head, frontal view.
Fig. 23. Head, dorsal view.
Fig. 24. Head, ventral view.
Fig. 25. Anterior end, lateral view.
Fig. 26. Male, posterior end, lateral view.
Fig. 27. Female, posterior end, lateral view.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Legends to Figs. 28–35.

Thelazia chungkingensis n.sp. Figs. 28–31.

Fig. 28. Head, frontal view.
Fig. 29. Head, dorso-ventral view.
Fig. 30. Male, posterior end, lateral view.
Fig. 31. Male, posterior end, ventral view.

Oxyspirura kaitingensis n.sp. Figs. 32–35.

Fig. 32. Head, frontal view.
Fig. 33. Head, lateral view.
Fig. 34. Male, posterior end, ventral view.
Fig. 35. Female, posterior end, lateral view.

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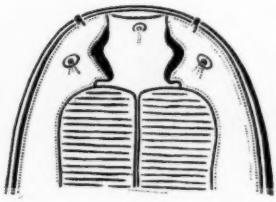

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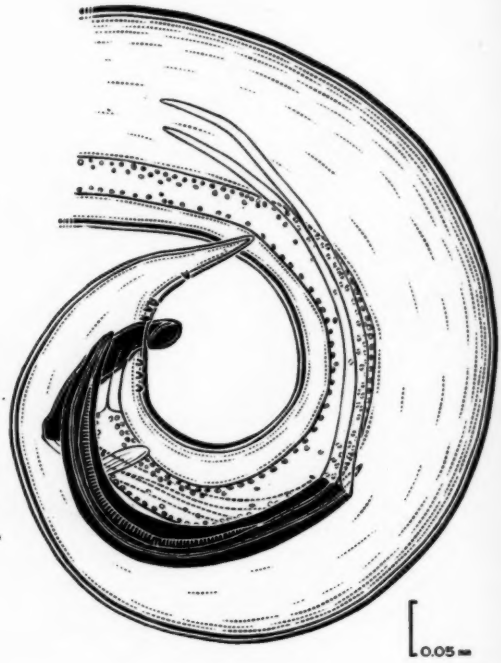

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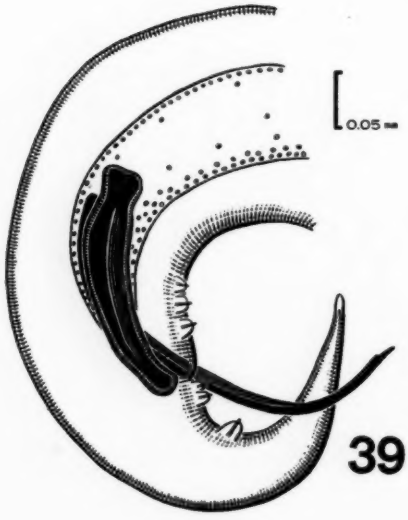

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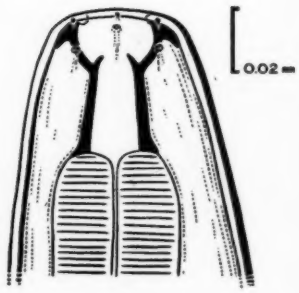

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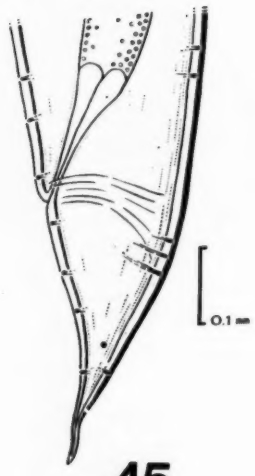
Legends to Figs. 36–40.

Fig. 36. *Oxyspirura kaitingensis* n.sp. Male, posterior end, lateral view.

Oxyspirura peipingensis n.sp. Figs. 37–39.

Fig. 37. Head, frontal view.
Fig. 38. Head, lateral view.
Fig. 39. Male, posterior end, lateral view.
Fig. 40. *Oxyspirura tsingchengensis* n.sp. Head, lateral view.



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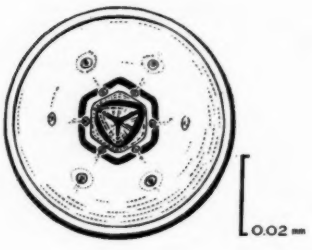

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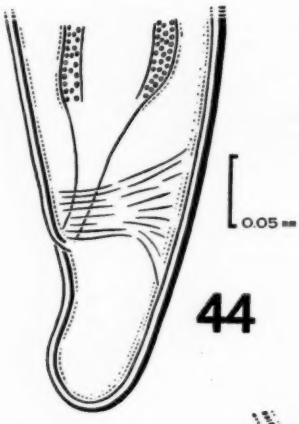

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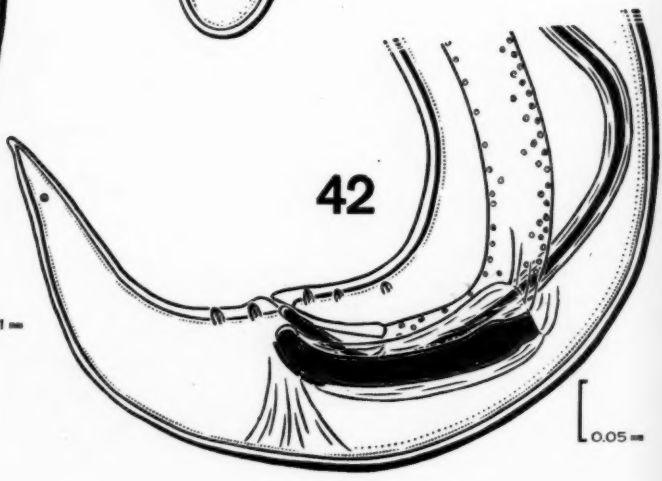

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Legends to Figs. 41–46.

Oxyspirura tsingchengensis n.sp. Figs. 41–43.

Fig. 41. Head, frontal view.
Fig. 42. Male, posterior end, lateral view.
Fig. 43. Female, posterior end, lateral view.
Fig. 44. *Thelazia chungkingensis* n.sp. Female, posterior end, lateral view.
Fig. 45. *Cosmocercoides pulcher* Wilkie 1930. Female, posterior end, lateral view
Fig. 46. *Pingus sinensis* n.g. et n.sp. Female, posterior end, lateral view.

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NOTE ON A SCHISTOSOMA CERCARIA WITH FOUR PAIRS OF FLAME CELLS IN THE BODY.

By R. G. ARCHIBALD and A. MARSHALL.

From The Wellcome Tropical Research Laboratories, Khartoum.

(With 1 Figure in the Text.)

The cercaria which forms the subject of this note was obtained from a consignment of *Bulinus truncatus* collected in Fasher in the Western Sudan. These molluscs were examined daily for a period of 3 weeks and some were observed to be shedding a pigmented cercaria, *Cercaria sudanensis* No. 8. On six successive days these molluscs were exposed to infestation with the miracidia of terminal spined ova from a typical case of Sudanese vesical bilharzia. The molluscs were examined at weekly intervals for a month and subsequently at daily intervals, and after a period of 83 days were found to be shedding furcocercous cercariae.

Measurements.

The cercariae in water were killed by gentle heat, and gave the following average measurements: Body 164 × 51 μ; variation in length 156–172 μ. Tail stem 220 × 32 μ; variation in length 212–228 μ. Furcus 74 × 13 μ; variation in length 62–80 μ.

Examined in water *in vitro* the cercariae were found to be present in all layers of the fluid and displayed the movements of swimming common to the schistosome cercariae. Microscopical examination (Fig. 1) of specimens in serum showed that the whole cercaria, with the exception of the extreme tips of the furcal rami, was covered with retrorse spines. In other characters it resembled morphologically the cercaria of *Schistosoma haematobium*, possessing three pairs of penetration or periacetabular glands with a corresponding number of gland ducts. The two anterior pairs of glands were more granular than the posterior pair. It had no pharnyx and no eye spots. The excretory system showed four pairs of flame cells in the body and one pair in the tail stem and, in addition, there were two pairs of ciliated areas. This cercaria differed from that of *S. haematobium* by having an additional pair of flame cells in the body which were given off from the posterior collecting tubules at the posterior extremity of the body. Like the cercaria of *S. haematobium* it developed in greyish sporocysts in the liver of the molluscs.

Animal experiment.

A healthy grey monkey, *Cercopithecus sebaeus*, was exposed by skin and oral routes to infestation with large numbers of these cercariae on two occasions at an interval of a week. Four months later the monkey was passing blood and

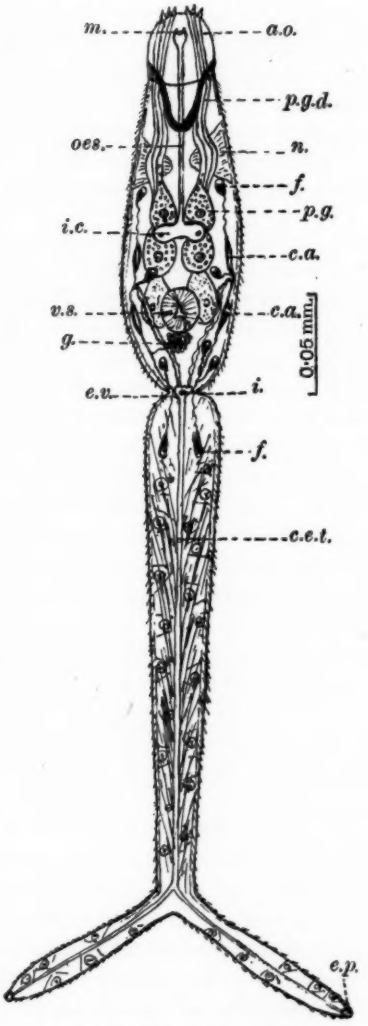

Fig. 1. A schistosoma cercaria.

Lettering: *a.o.* anterior organ; *c.a.* ciliated area; *c.e.t.* caudal excretory tube; *e.p.* excretory pore; *oes.* oesophagus; *e.v.* excretory vesicle; *f.* flame cell; *g.* genitalia; *i.* island of Cort; *i.c.* intestinal caecum; *m.* mouth; *n.* nervous system; *p.g.* penetration gland; *p.g.d.* penetration gland duct; *v.s.* acetabulum.

Note. The figure represents a camera lucida drawing.

mucus in its faeces, together with many terminal spined ova. These gave an average measurement of 144 × 60 μ with variation in length from 128–172 μ. The monkey was autopsied and showed many adult male and female *S. haematobium* in the mesenteric veins. The fertilised adult females contained numerous terminal spined eggs. The adults were measured unfixed, and gave the following measurements: adult males 6·5–7 × 0·5 mm.; adult females 9·5 × 0·125 mm. The mucosa of the colon was congested and thickened and showed many terminal spined eggs in the sub-mucosa. The bladder was normal and no adults were present in the portal or iliac veins.

Remarks.

Cort (1917) has drawn attention to the number and position of the flame cells in the different furcocercous cercariae, and it has been generally accepted that the cercaria of *S. haematobium* and *S. mansoni* possess only three pairs of flame cells in the body.

Of the large numbers of cercaria of *S. haematobium* and *S. mansoni* that we have examined, this has been the only occasion in which we have found four pairs of flame cells in the body. Our observations on this point were made independently of each other. In serum preparations there was no difficulty in locating the position and number of these flame cells, which continued their activities for 2 to 3 hours. Soparkar (1921) has described a schistosoma cercaria in India, *S. spindalis* (Montgomery), with four pairs of flame cells in the body, but it differs from the cercaria we have described in possessing five pairs of mucin or penetration glands. The experimental infection in a monkey proved beyond doubt that we were dealing with a schistosoma cercaria, and we believe that it was probably an aberrant form of the cercaria of *S. haematobium*. A point of interest was the long period—viz. 83 days—for the development of the mature cercariae in the molluscan host. This may have been due to the fact that the majority of the molluscs were already naturally infested with a pigmented cercaria.

Summary.

1. A brief account is given of a schistosoma cercaria obtained from *Bulinus truncatus* possessing four pairs of flame cells in the body.

2. A monkey, *Cercopithecus sebaeus*, was experimentally infected with this cercaria, adult male and female *S. haematobium* being formed in the mesenteric veins, and terminal spined ova in the sub-mucosa of the colon.

3. The view is expressed that this cercaria was probably an aberrant form of the cercaria of *S. haematobium*.

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FERTILISATION AND EGG FORMATION IN A DIGENETIC TREMATODE, *PODOCOTYLE ATOMON*.

By E. IDRIS JONES, B.Sc. (London).

(With 3 Figures in the Text.)

Few records have been made of the process of fertilisation in the Digenea. Nicoll (1907) observed it in *Podocotyle* and states that it lasted but 10 min., and MacCallum (1913) has given an account of fertilisation in *Microcotyle*, one of the Monogenea.

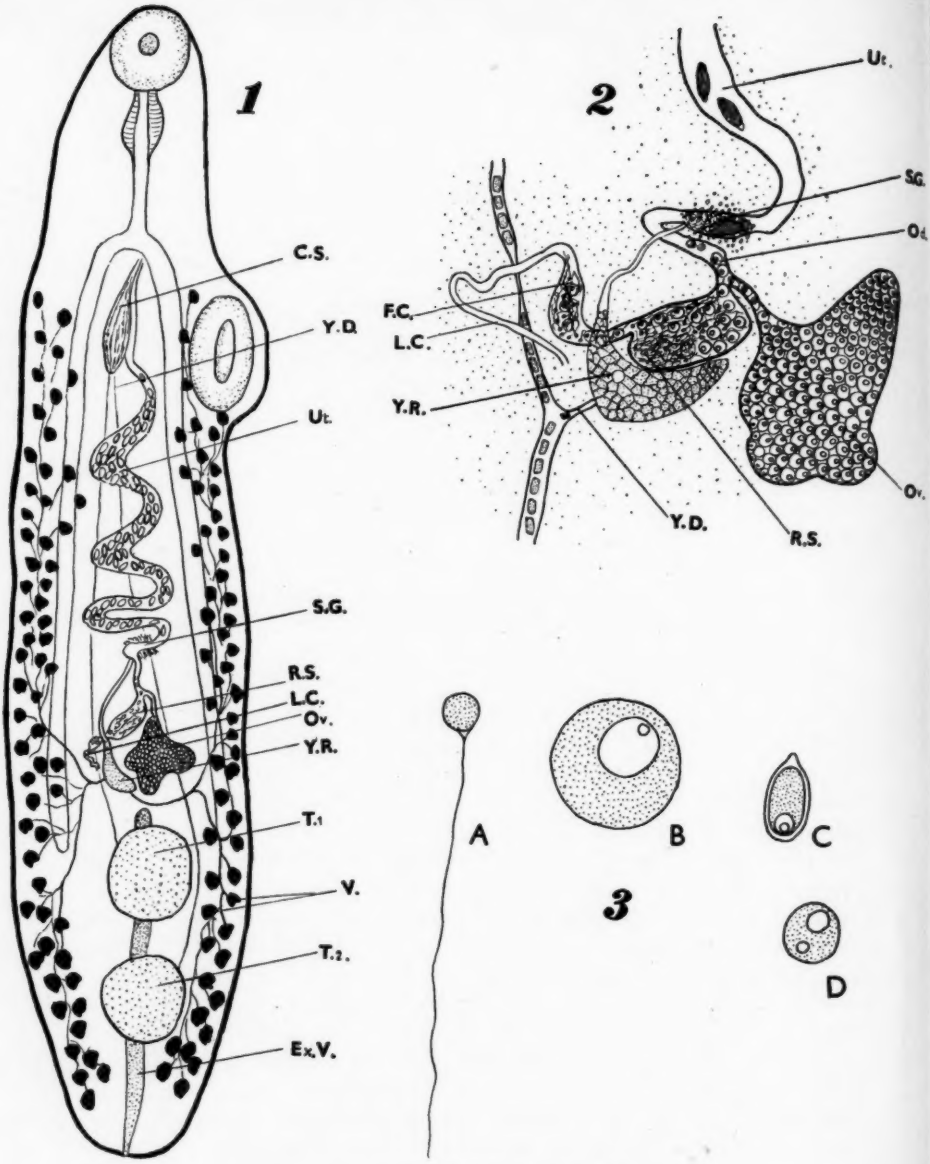
An opportunity having presented itself for the study of the fertilisation of the ova and of egg formation in the digenetic trematode *Podocotyle atomon*, an account is given herewith.

The specimen was obtained from the stomach of *Syngnathus acus* trawled north of Drake's Island, Plymouth, 17. ix. 31, and was studied under high and low powers in normal saline which was being continuously replenished.

Podocotyle atomon (Rud.) Fig. 1 (Odhner, 1906; Nicoll, 1907) is characterised by the following features: body devoid of spines; length, 2·5–3 mm.; oral sucker circular, 1/10 length of body; ventral sucker elliptical; distance between suckers 1/5–1/3 length of body; prepharynx present; oesophagus twice as long as pharynx; testes 2, in posterior region of body; ovary 4-lobed; vitellaria diffuse, not extending in front of ventral sucker; genital aperture midway between suckers.

Entering the receptaculum seminis from the right is Laurer's canal which expands immediately before entering the receptaculum into a chamber which I propose calling the *fertilisation chamber*. On the left the receptaculum receives a duct from the ovary and near the same point gives off the oviduct leading to the shell gland. The shell gland receives a duct from the yolk reservoir and the uterus emerges from the shell gland. Each ovum possesses a relatively large, highly refractile nucleus not centrally situated. Some giant spermatozoa were observed 5/3 the size of the ordinary spermatozoa.

The spermatozoa were first observed as a wriggling, seething mass in the receptaculum seminis. By contraction of the walls of the ovary, ova were forced into the receptaculum seminis and from there a few passed at intervals into the fertilisation chamber. Spermatozoa could be seen freeing themselves from the mass and swimming actively round the ova which were kept in constant motion by their lashing. Occasionally a spermatozoon could be seen entering an ovum, the male pronucleus coming to lie in the cytoplasm of the ovum, but fusion of the two pronuclei was not seen. At intervals the walls of the fertilisation chamber contracted and ova were forced back into the



Figs. 1–3. *Podocotyle atomon* (Rud.).

Fig. 1. Adult from stomach of *Syngnathus acus*.
Fig. 2. Ovary and associated structures.
Fig. 3. A, spermatozoon; B, ovum; C, egg; D, fertilised ovum.

Lettering: *C.S.* cirrus sac; *Ex.V.* excretory vesicle; *F.C.* fertilisation chambers; *L.C.* Laurer's canal; *Od.* oviduct; *Ov.* ovary; *R.S.* receptaculum seminis; *S.G.* shell gland; *T* 1 and *T* 2, testes; *Ut.* uterus; *V.* vitellaria; *Y.D.* yolk duct; *Y.R.* yolk reservoir.

receptaculum whose walls also contracted at intervals, forcing ova into the oviduct. Rarely ova would pass along Laurer's canal very slowly, but this was probably due to pressure of the coverslip.

Spermatozoa could still be seen swimming about and fertilisation occurring at the end of 6½ hours.

At the same time as the above process was occurring the formation of the egg in the shell gland was taking place. By contraction of the walls of the yolk reservoir sixteen yolk cells were constricted off from the main mass and passed along the duct to the shell gland. This process occupied 1¼ hours. The yolk cells arranged themselves round the ovum, which was already in the shell gland, and globules of secretion could be observed to form round the ovum and yolk cells. These globules became less distinct and a shell gradually appeared which was thick in 1½ hours, and at the end of 2 hours the egg started to leave the shell gland and passed up into the broad much-coiled uterus which already contained several hundred eggs.

The history of the ovum from the time it leaves the ovary to the time it enters the uterus as an egg complete with yolk and shell has thus been traced.

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TWO NEW PARASITIC COPEPODS FROM CEYLON.

By P. KIRTISINGHE, B.Sc.

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(With 7 Figures in the Text.)

1. **Pennella biloba** n.sp. (Figs. 1–3).

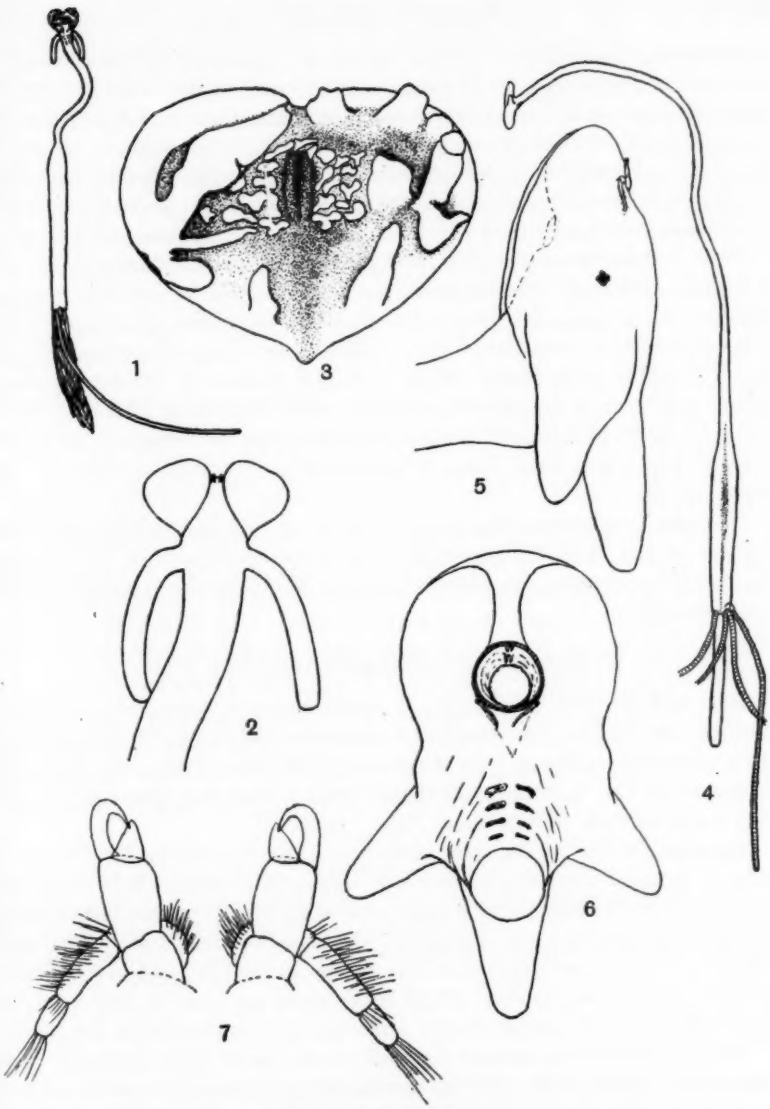
Host and Record. A single female was found attached close to the left pelvic fin of a *Histiophorus brevirostris* Playfair caught off the south-west coast of Ceylon in January, 1932. One of the egg-strings was missing.

Description. The head is twice as broad and is marked dorsally by two grooves which divide it into a median somewhat triangular area and two lateral lobes (Fig. 2). The base of the triangular area passes into the neck. The anterior end of the flattened head is very much inclined to the ventral side so that from a lateral view the head is wedge-shaped. The ventrally inclined anterior end of the head is shaped like a heart and on this there are two kinds of papillae. Arising from its border are large irregularly arranged papillae, while a group of much smaller papillae lies on either side of the mouth (Fig. 3).

Immediately behind the head a pair of horns originates from the base of the neck and at right angles to it. They are of uniform diameter and bluntly rounded off distally. A short distance from their origin they bend backwards and lie below the plane of the head and neck. The neck is almost uniformly round and separated by a slight constriction from the genital segment which is broader than the neck and tapers gently towards its posterior end. The neck and genital segment are of the same length. There are no transverse ridges on either the genital segment or the abdomen. The appendages which are borne on the ventral and lateral faces of the abdomen are red-shaped, unbranched processes. The egg-strings are longer than the genital segment.

I am unable to make out the first pair of antennae, but the second antennae are represented by a pair of short three-jointed processes on the dorsal side of the head at the apex of the triangular area (Fig. 2). The four pairs of thoracic legs retain only their pigmented basal joints. The distance separating the second and third pairs is rather more than that between the first and second or third and fourth pairs.

Dimensions (in mm.). Head, length 1, breadth 2; horns 3; neck 12; genital segment 12; abdomen 7; egg-strings 16; entire length 32.



Legends to Figures.

Pennella biloba n.sp. (Figs. 1–3).

Fig. 1. Entire animal; ventral view.
Fig. 2. Head and horns; dorsal view.
Fig. 3. Anterior surface of head showing papillae.

Lernaeenicus hemiramphi n.sp. (Figs. 4–7).

Fig. 4. Entire animal.
Fig. 5. Lateral view of head and horns.
Fig. 6. Ventral view of head.
Fig. 7. Antennae.

Remarks. According to Wilson (1917) the species of *Pennella* can be divided into two groups: (1) forms of length 50 mm. or less, and (2) forms of length 100 mm. or more. Leigh-Sharpe (1928) also finds that the species of *Pennella* in the British Museum fall naturally into two groups: (*a*) small forms in which the neck is definitely shorter than the trunk, including *P. sagitta* Lin. and *P. orthagorisci* Wright, and (*b*) large forms in which the neck is definitely longer than the trunk, including all the remaining species.

This grouping is very artificial and gives no indication of interspecific relationship. Although *P. orthagorisci* has a neck which is definitely shorter than the trunk (genital segment), it cannot be described as a small form. It ranges in length from 15 to 18 cm., which is more than the average length of the so-called large forms. In fact, Wilson includes it among the large forms. Neither does the proportion of the neck to the trunk afford a reliable guide, for in *P. biloba* and *P. tridentata* (Listowsky) the neck and trunk are of equal length and these forms would therefore not fall into either of the above groups.

The affinities between the species appear to be based chiefly on (1) the papillae of the head, (2) the origin and shape of the horns, and (3) the abdominal appendages. In these characters *P. biloba* shows affinities with *P. sagitta* Lin.

2. **Lernaeenicus hemiramphi** n.sp. (Figs. 4–7).

Host and Record. The species is described from two specimens found infesting the gar-fish, *Hemiramphus xanthopterus* Cub. and Val. One of these (A) is an immature female from a fish caught off Point Pedro, the other (B), illustrated in Fig. 4, is an adult female from a dead fish picked up on the coral reef near Galle in September, 1931.

Description. The general form of the animal is long and slender. The head, which is rounded in front, is almost as long as it is broad. It is somewhat flattened dorso-ventrally, with a depression along its mid-ventral line in which the round mouth is placed. Posteriorly the head is provided with three stiff, chitinous horns—a median horn about as long as the head and in a line with its long axis, and two shorter, lateral horns which are inserted very nearly at right angles with the median horn. A median eye is embedded in the head.

The long neck arises almost vertically to the head. It is uniformly wide and passes imperceptibly into the genital segment which has a diameter of about three times that of the neck and is broadest a short distance from its anterior end. It is marked ventrally by a median groove. The abdomen is cylindrical with a diameter of about half that of the genital segment. It is destitute of anal laminae or setae and is rounded off at its extremity. The genital segment and abdomen are covered with a thin layer of pigment having a deep violet colour.

The two pairs of antennae arise close together on the top of the head. The first antennae are three-jointed and are beset with setae on the outer

faces of the first and second joints as well as the distal ends of the second and third joints. The second antennae are also three-jointed, but the joints are stouter, have no setae, and the distal joints form chelae which shut down against a projection of the inner side of the second joints (Fig. 7). I have not been able to distinguish a pair of mandibles, but there is a pair of maxillae behind the mouth. The entrance to the mouth is guarded by a ring of thickened chitin within which anteriorly are placed two pairs of spines one behind the other (Fig. 6). The four pairs of thoracic legs with characteristically pigmented basal joints are placed at equal distances apart on the ventral side of the base of the neck.

Dimensions (in mm.).

	Specimen A	Specimen B
Head and median horn	2	2½
Neck	19·5	26
Genital segment	6	8
Abdomen	8	7
Egg-strings	—	14
Entire length	34·5	42

Remarks. Both specimens were attached to the host in such a way that practically the entire neck was within the flesh of the host with the head projecting into its body cavity. The head and most of the neck of the parasite was enveloped by a cyst. In B this cyst was so tough that while dissecting it away the thoracic legs came off with it. The genital segment and abdomen of this specimen were densely grown over with at least two kinds of red algae. Also it has the unusual number of four egg-strings, one from the opening of the right oviduct and three from that of the left. The advanced state of this specimen leaves little room for doubt that it was directly responsible for the death of its host.

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ARGULUS ROTHSCHILDI N.SP., A PARASITIC BRANCHIURID OF *ABRAMIS BRAMA*.

By W. HAROLD LEIGH-SHARPE, M.Sc. (Lond.).

(With 5 Figures in the Text.)

Argulus rothschildi.

(Figs. 1–5.)

Habitat and record: About forty specimens, of both sexes, collected and presented to me by Miss Miriam Rothschild from a bream *Abramis brama* (wt. 13 lb. 1 oz.) taken from the Tring reservoir, December, 1931.

Body (Fig. 1). Carapace elliptical, much longer than wide; posterior sinus two-fifths the length of the carapace. Cephalic area projecting considerably and well armed with denticles. Carapace lobes not reaching the abdomen and not covering the fourth pair of pereiopods. *Pouches* (Fig. 1, *P.*) two pairs, one, the anterior, very small.

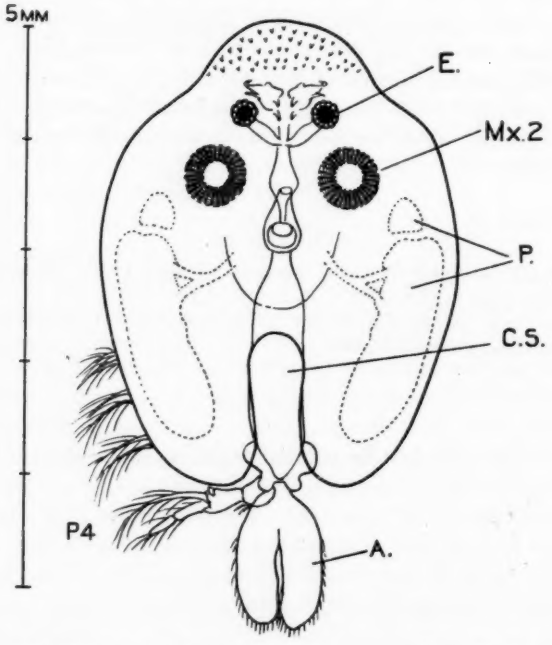

Fig. 1. *Argulus rothschildi* n.sp. ♂ in dorsal aspect. *E.* = compound eye; *Mx.* 2 = second maxillae; *P.* = pouches; *C.S.* = median sinus of carapace; *A.* = abdomen; *P* 4 = fourth pereiopod.

Abdomen. Elongated, one-third the length of the rest of the body, not much difference in length in the two sexes, elliptical; anal sinus narrow, more than half the length of the abdomen. Sides of abdomen parallel, and covered, as well as the extremities and sides of sinus with long fine setae as in *A. coregoni*. Papillae absent.

Dimensions (in mm.) of an average specimen:

Total length of animal: 5·2.
Length of carapace: 3·9.
Length of abdomen: 1·3.
Width of carapace: 3·25.

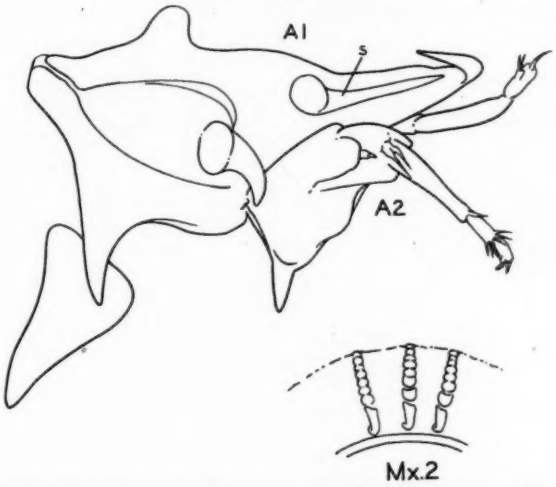

Fig. 2. *Argulus rothschildi*, appendages. *A* 1 = antennule; *A* 2 = antenna; *S.* = specific spine; *Mx.* 2 = chitinous rays of the second maxilla.

Appendages. *Antennules* (Fig. 2, *A* 1). Base two-articled. Proximal article broad, flat, triangular, the smaller of the two, and prolonged posteriorly into a large stout chitinous spine. The distal article is considerably elongated at right angles to the proximal, and hence at right angles to the central axis; it terminates in a strong sickle-shaped hook which is curved ventrally. Parallel with this latter is a specific spine (Fig. 2, *S.*) said to be characteristic of *A. foliaceus* (Jurine, 1806), which, curiously, is visible in all my specimens, irrespective of sex, mounted dorsal side up but not in those mounted ventral side up. A stout but somewhat smaller hook is present on an enlarged base near the proximal end of the distal article. The terminal portion of the antennule, which has three articles, the middle one being much the longest, is articulated to the distal article alongside the huge chitinous hook, the terminal article bearing 3 setae, one terminal and two on a papilla.

Antennae (Fig. 2, *A* 2). Base two-articled. Proximal article stout, cylindrical, produced backward near the median line into a blunt chitinous spine

similar to that on the antennule and in line with it; a lateral process is present ending in a two-articled projection, not recorded in other species. Distal article stout, with a bifurcated lateral process ending in two setae, not recorded in other species. The three remaining articles much narrower than the basal ones, the proximal one very long, the terminal very short, all three articles being tipped with setae, and flexed until they form nearly a right angle with the basal article. The *mouth-parts* have been figured by very few authors (Fig. 3). The oral aperture is triangular rather than an elongated slit. Upper lip toothed at the apex and sides as well as beset with large teeth at the outer corners. Lower lip not toothed. Labial palps elliptical rather than triangular. I am unable to make out the sting.

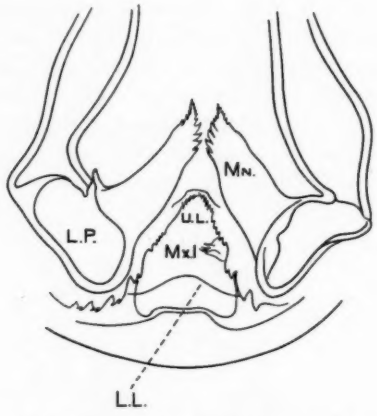

Fig. 3. *Argulus rothschildi*, mouth-parts. *U.L.* = upper lip; *L.L.* = lower lip; *L.P.* = labial palps; *Mn.* = mandibles; *Mx.* 1 = first maxilla.

Mandibles (Fig. 3, *Mn.*). Not quite a pair, (as figured by Claus (1875) in *A. foliaceus*) very large and stout, not curved; strongly chitinised teeth, not of equal size as usually figured but with four more proximal large ones and smaller distal ones on *both* sides of the apex. The large teeth almost meet in the mid-line of the gullet above the mouth opening.

First maxillae (Fig. 3, *Mx.* 1) difficult to observe but appear to consist of a single article and terminate in three spines.

Second maxillae (Fig. 1). Sucking discs small, diameter one-sixth that of the carapace. The arrangement of the chitinous rays of the border membrane is shown in Fig. 2, *Mx.* 2; one J-shaped basal rod and seven subspherical articles in a row.

Maxillipedes (Fig. 4, *Mp.*). Five-articled with a short stout proximal article and four longer terminal ones. The ventral surface of all these articles, over the greater part of its area, is armed with denticles pointing backwards. The proximal article has on its ventral surface a raised area armed with denticles

and is produced into three strong spines, forming the comb. The terminal article ends in two processes and a sub-apical pupilla ending in a process. This appendage varies little in the different species.

The first two pairs of *Pereiopods* possess a flagellum (Fig. 4). All four pairs have a two-articled base. The endopodites of the last two pairs are two-articled (Fig. 5). The basipodite of the third pereiopod in the male bears the usual semen capsule, and the coxopodite of the fourth pereiopod bears the usual semen peg (Fig. 5, *P.*). The peg is here figured on an enlarged scale and

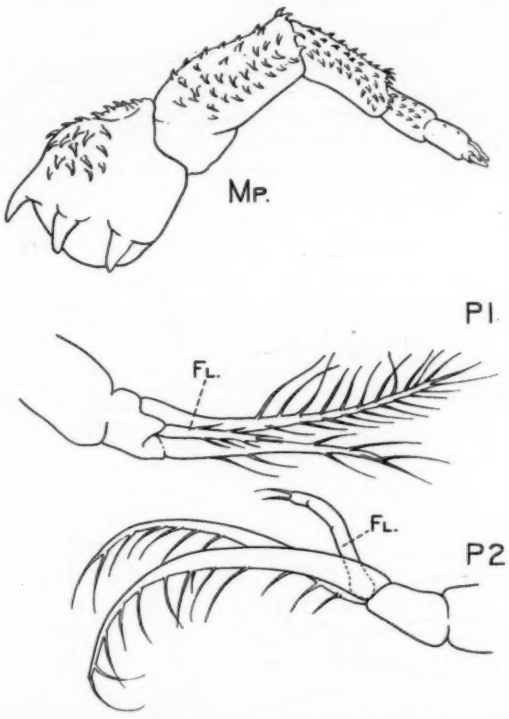

Fig. 4. *Argulus rothschildi*, appendages. *Mp.* = maxillipede; *P* 1 = first pereiopod; *P* 2 = second pereiopod; *Fl.* = flagellum.

consists of a large tubercle at the base of the exopodite and covered centrally with denticles. From behind its centre arises a long curved spine conical in shape, whose diameter is one-third that of the tubercle. The spine curves in such a way as never to be in the same focus as the peg. Between the peg and the exopodite is an auricular expansion bearing curved spines proximally. The basipodite has an elevated area about its centre bearing denticles. The coxopodite carries at least three of the usual extremely long setae. The basipodite bears a small process on a papilla distally near the endopodite.

Determination of species. We here appear to be confronted by the anomaly of an *Argulus* having a trunk and appendages like that of *A. foliaceus* and an abdomen like that of *A. coregoni*. The difficulty in founding a new species is threefold: (1) The additional details of the antenna may have been overlooked by previous observers. (2) The mouth-parts have been described for very few species, but the mandibles, teeth on the upper lip, and the labial palps differ profoundly from those figured by Claus (1875) for *A. foliaceus*. (3) I may have overlooked the papillae on the abdomen.

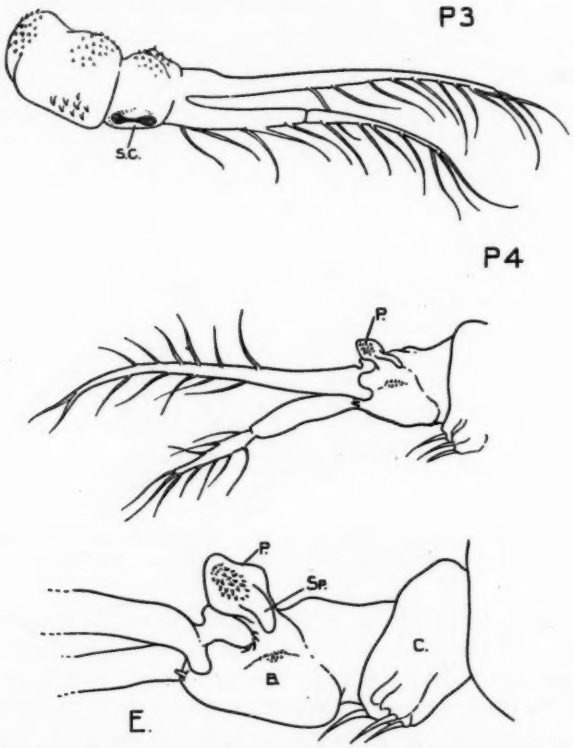

Fig. 5. *Argulus rothschildi*, ♂, appendages. *P3* = third pereiopod; *S.C.* = semen capsule; *P4* = fourth pereiopod; *E.* = enlarged proximal portion of fourth pereiopod; *P.* = semen peg; *Sp.* = spine; *B.* = basipodite; *C.* = coxopodite.

Specific characters. For the present I am relying on the following characters to establish this as a separate species and not a variety of *A. foliaceus*. Additional details on the antenna. Mandibles with two types of teeth; small ones on *both* sides of apex. The character and disposition of teeth on the upper lip. The character of the chitinous rays of the sucking discs. (The presence of flagella on the first two pereiopods.) Abdomen without papillae, the terminal lobes covered with long curved setae.

CONCLUSION.

It is open to accept *A. rothschildi* (1) as a new species on the specific host *Abramis brama*; (2) a variety of *A. foliaceus* (even perhaps of *A. coregoni*) permanently settled on *A. brama*; or (3) as a form of *A. foliaceus* on *A. brama* as an antipathetic host.

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ON FIVE NEW SPECIES OF TICKS (ARACHNIDA IXODOIDEA).

IXODES PETAURISTAE, I. AMPULLACEUS, DERMACENTOR IMITANS, AMBLYOMMA LATICAUDAE AND *APONOMMA DRACONIS*, WITH NOTES ON THREE PREVIOUSLY DESCRIBED SPECIES, *ORNITHODORUS FRANCHINII* TONELLI-RONDELLI, *HAEMAPHYSALIS COOLEYI* BEDFORD AND *RHIPICEPHALUS MACULATUS* NEUMANN.

By CECIL WARBURTON, M.A.

From the Molteno Institute of Parasitology, Cambridge.

(With Figures 1–7 in the Text and Figures 8 and 9 on Plate XXIII.)

Ixodes petauristae n.sp.

Male unknown.

Female (Fig. 1): *Scutum* (2·2 × 1·8 mm.) much longer than broad, with well-marked lateral folds on the anterior half; cervical grooves rather far apart at origin, then faint and divergent; some very fine punctations on the lateral folds and in the area between them and the cervical grooves, the posterior region very glossy and almost devoid of punctations. Emargination very slight. *Venter*: vulva between coxae IV. Genital grooves only slightly divergent, not extending beyond the anus. Anal groove horseshoe-shaped, then shallow and divergent. Spiracles nearly circular and very large (larger than coxa IV). *Capitulum* long; basis triangular, without cornua or auriculae, its ventral surface divided by a transverse line. Porose areas large, subrectangular, with narrow interval. Palps fairly stout; hypostome lanceolate, dentition 2|2, about twelve teeth per file, the outer the stronger. *Legs*: coxa I *deeply cleft into two equal flat teeth*, recalling that of *Rhipicephalus*, and very unusual in *Ixodes*; coxae II–IV with an external tooth, diminishing in size. Tarsi long (especially tarsus I) and tapering, the pad nearly as long as the rather weak claws.

Described from a single ♀ taken in Ceylon, May, 1930, from *Petaurista phillipensis* Link (Sciuridae), and communicated by Mr J. J. Cox of the Museum, Tring.

Type in Cambridge (N. 3872).

Of known *Ixodes* this fine species most resembles *I. acutitarsus* Karsch, from which it is easily distinguished by its smaller size, the different shape of the scutum, and the flattened teeth on coxa I.

Ixodes ampullaceus n.sp.

Male unknown.

Female (Fig. 2): body flask-shaped; lateral portions of the dorsum with numerous conspicuous hairs, directed inwards; median region less hairy and entirely destitute of hairs posteriorly. *Scutum* (1·3 × 0·8 mm.): longer than broad, broadest at the anterior third, glossy, moderately punctate with small discrete punctations; cervical grooves sigmoid, not invading the posterior third of the scutum; lateral grooves barely indicated. *Venter*: vulva between coxae IV; genital grooves narrow at first, widest at level of anus. Anal groove closed, nearly circular; posterior region of venter hairy. Spiracles transverse-oval, of moderate size, rather far removed from coxa IV. *Capitulum* long and slender. Basis without cornua. Porose areas large, pear-shaped, the narrow end of the pear attaining the posterior border at its outer extremity; the interval wide. Auriculae entirely absent. Hypostome lanceolate, the dentition rather obscure, there being a single external row of about nine stout teeth on either side, the other teeth being very fine and sharp. *Legs* smaller and weaker than in *I. rasus*, but similar, except that there is a more pronounced spine on coxa I. The coxae diverge greatly, the peculiar shape of the body causing coxae IV to be very far apart.

Described from 2 ♀ taken by Mr Rupert L. L. Hart on the "edible rat," *Cricetomys ganibicus*, in Uganda.

This species is very nearly allied to *I. rasus* Nn., and a single example might have suggested a freak specimen of that rather variable species, but the two females, being exactly alike, show that the flask-like shape is normal, and other differences appear on close examination. The basis capituli in its ventral aspect is small, rounded, and *entirely destitute of auriculae*, and the spur on coxa I is well marked.

Type in Cambridge (N. 3873).

Dermacentor imitans n.sp.

Male (Fig. 3): length 4–5 mm. (capitulum included), breadth 3–3·5 mm. *Scutum* rather narrow in front, widest at the posterior third; punctations few, shallow, inconspicuous; cervical grooves small sub-circular pits; lateral grooves well marked, beginning behind the very inconspicuous eyes and ending in front of the first festoon. Festoons well marked, short, their ventral scutes, (except the median) in most examples, produced posteriorly into chitinous tubercles similar to those on *Amblyomma mantiquirense* (in company with which species the specimens were taken). The specimens show in varying degree traces of white markings on the brown scutum, mostly obsolescent. Their position is indicated by the dotted lines in the figure. The most persistent are the white patches on the external festoons, and next are the linear markings on the scapulae. The whitish round blotches in front of the sub-median festoons are dimly visible in most specimens, but only a few show traces of

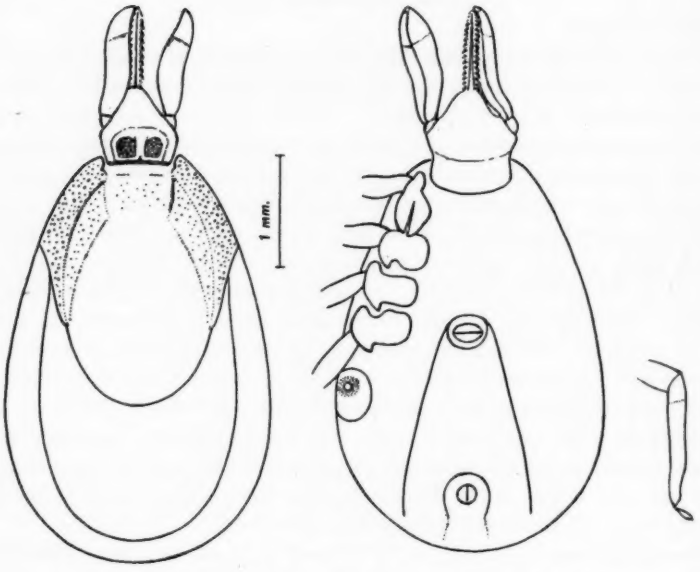

Fig. 1. *Ixodes petauristae* n.sp. ♀. Dorsal and ventral aspects and tarsus IV.

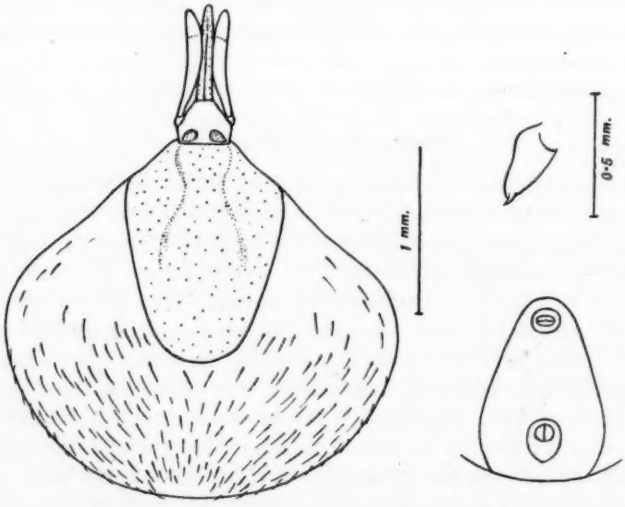

Fig. 2. *Ixodes ampullaceus* n.sp. ♀. Dorsal aspect; coxa I, posterior portion of venter.

white near the lateral grooves. *Capitulum*: basis rectangular, broader than long, with stout blunt cornua. Palps massive, articles 2 and 3 about equal in length and taken together somewhat broader across than the basis. Hypostome spatulate, well covered with fairly equal rather blunt teeth 3|3. *Venter*: spiracle very short comma-shaped with blunt tail. There is a dark anterior stigma, but all the granulations are exceedingly fine. Anal groove a shallow curve, with very ill-marked caudal prolongation. *Legs*: coxa I small, with the inner spur broad and blunt, the outer spur needle-like. Coxae II and III with very slight outer spur. Coxa IV about as broad as long, only very slightly bulging posteriorly, and practically devoid of spurs. Tarsus IV rather short, sloping abruptly and with two strong ventral spurs.

Female (Fig. 4): *Scutum* nearly circular (about 1·5 mm.); slightly angular at the very inconspicuous eyes. Punctations nearly absent but a few large shallow punctations appear, especially in the lateral groove region. Cervical grooves small oval pits, far apart; lateral grooves very shallow broad depressions chiefly indicated by the somewhat raised lateral fold. There are traces of a white pattern, but a few linear streaks are all that remain. *Capitulum*: basis with blunt diverging cornua, porose areas large, circular, with very slight interval; palps longer and less massive than in the ♂. Dentition 3|3, *Venter*: spiracle small (much smaller than coxa IV) with large oval stigma and fine granulation. *Legs* as in the ♂ except as regards coxa IV.

Described from 12 ♂♂, and 1 ♀ taken by Mr W. J. Hamilton, Jun., on a peccary (*Pecari angulatus*) at Turrialba, Costa Rica, on August 1st, 1927, and sent to Cambridge by Prof. R. Matheson. In the same tube were specimens of *Amblyomma mantiquirense*.

Types in Cambridge (N. 3874).

Amblyomma laticaudae n.sp.

Male (Fig. 5): *Scutum* longer than broad (3 × 2·6 mm.), inornate, with fairly numerous fine discrete punctations; no lateral grooves; cervical grooves short, sub-parallel; festoons fairly long, with shallow partitions; pseudoscutum indicated by a slight raising above the general surface. Eyes inconspicuous, but present in all three specimens on careful observation. *Venter* of the same colour (brown) as the scutum, rather corrugated posteriorly; spiracles large, short comma-shaped. *Capitulum* rather small; basis broader than long; punctate like the scutum; without cornua; hypostome spatulate, armed at its distal end with 3|3 fairly stout teeth, about five in each row. *Legs* slightly paler than the body; coxa I with two small blunt equal teeth, well separated; coxae II–IV with a small rather sharp external tooth. *Tarsi* rather short and stout, sloping somewhat abruptly. Pad half as long as the claws.

Female (Fig. 6): the gorged specimen measured 12 × 8 mm. *Scutum* (1·2 × 1·4 mm.) cordate with well-rounded angles, rather convex, punctations small, discrete, not numerous. No lateral grooves; cervical grooves reaching the posterior border. *Venter*: vulva rather anterior to coxae II; spiracle large,

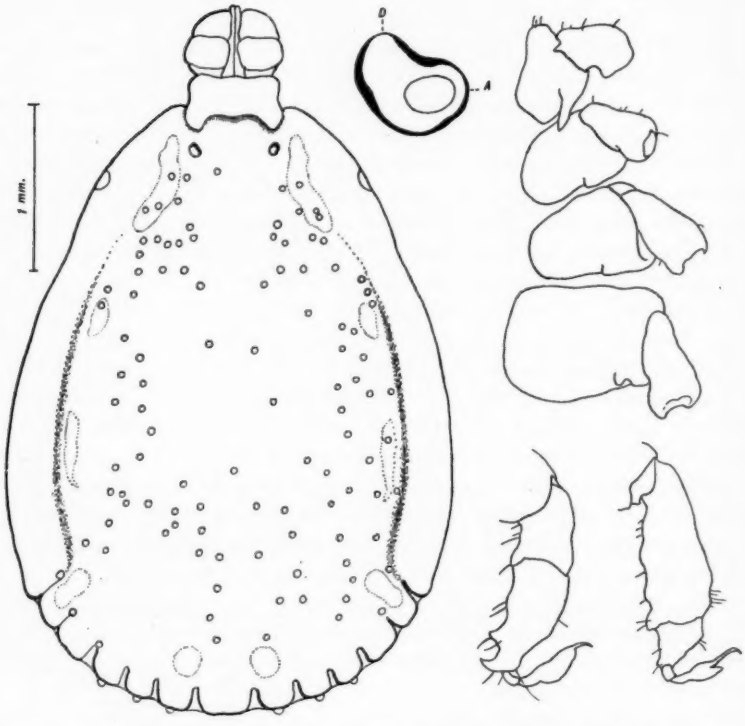

Fig. 3. *Dermacentor imitans* ♂. Dorsal aspect, spiracle, coxae and tarsi I and IV The dotted areas indicate traces of ornamentation.

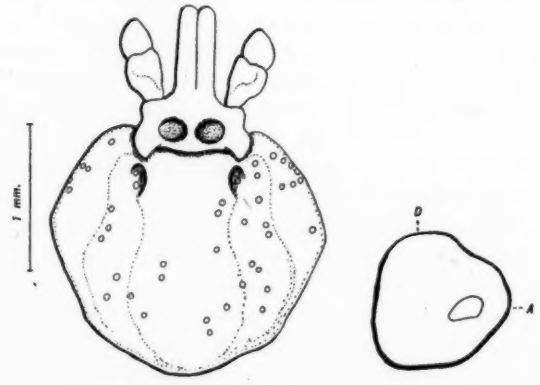

Fig. 4. *Dermacentor imitans* ♀. Capitulum, scutum and spiracle. Inconspicuous eyes as in ♂, omitted through error.

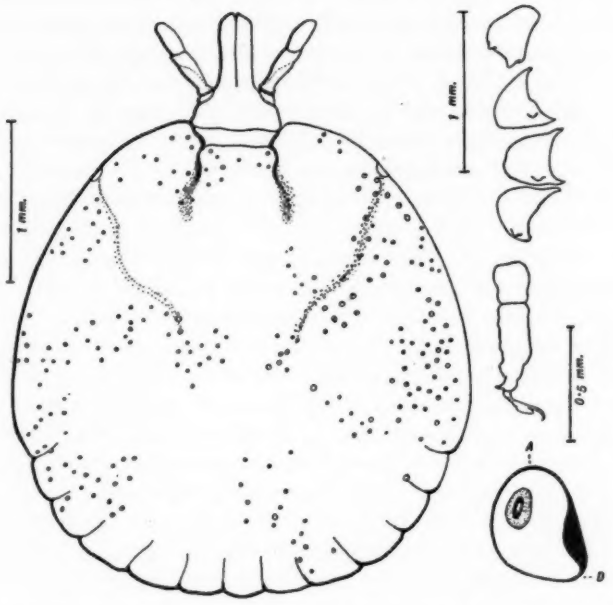

Fig. 5. *Amblyomma laticaudae* n.sp. ♂. Dorsal aspect, coxae, tarus IV and spiracle.

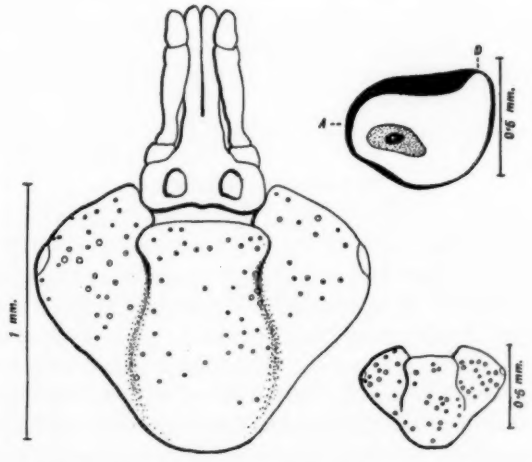

Fig. 6. *Amblyomma laticavdae* ♀. Capitulum, scutum and spiracle, and scutum of nymph.

sub-rectangular; anal groove ogival, the anus far from the posterior end in the gorged specimen. *Capitulum* longer than in the ♂; basis broader than long; porose areas circular, of moderate size, the interval equal to their diameter. Cornua absent. Palps and hypostome much longer than in the ♂; the distal end of the hypostome armed with 4|4 teeth, the inner row very small. *Legs* rather weak; armature as in the ♂.

Nymph with the general characters of the ♀, but the scutum is broader than long (Fig. 5) and the punctations are deeper and more conspicuous.

Described from 1 ♂, 1 ♀ (gorged) and 1 nymph taken from a sea-snake, *Laticauda colubrina*. The ticks were adhering to the skin, shed in captivity, at the Raffles Museum, Singapore, and were sent to Cambridge by the Assistant Curator, Mr Norman Smedley, who adds the following note: "The large ♀ and others were of the same grey as the snake and usually attached to the grey parts of the body, although I observed one on a black stripe. *Laticauda colubrina* belongs to that group of the sea-snakes possessing broad ventrals, and spends quite a considerable part of its time out of water, but even so the survival of the ticks while the snake is submerged seems remarkable."

The tick belongs to a group apparently connecting *Amblyomma* and *Aponomma*, and very difficult to differentiate because they seem to present no salient features, all the most distinctive characters such as ornamentation and peculiar leg armature being absent. The singularity of its host points to a specific difference, but there are few characters on which to found a diagnosis.

In 1910 S. Hirst and L. F. Hirst described (*Ann. and Mag. Nat. Hist.* **6**, 304) a tick from a sea-snake in the Solomon Islands under the name of *Amblyomma nitidum*, and Sharif (*Records of the Indian Museum*, **30**, Pt 3, p. 326) states that in the Indian Museum there are specimens of all stages from Port Blair, Andaman Islands. *A. nitidum* has very distinct eyes, and the dentition of the ♂ is 4|4. In the specimens here described the eyes were so feeble that they were at first missed, and the ticks ascribed to the genus *Aponomma*. Moreover the ♂ dentition is 3|3.

Types in the British Museum (Nat. Hist.).

Aponomma draconis n.sp.

Male (Fig. 7): *Scutum* (2·6 × 3 mm.) broader than long, broadest posteriorly, ornate, with three characteristic light markings on a nearly black ground—a small central spot and two pear-shaped lateral markings (see Fig. 7); the whole surface densely pitted with shallow punctations of two sizes—moderate and very small. Emargination slight; cervical grooves short and deep; no lateral grooves, festoons short and ill-defined. *Venter* of a lighter colour; spiracles long, comma-shaped. *Capitulum* of moderate length and of the colour of the scutum; basis triangular with slight rounded cornua, no auriculae; hypostome spatulate, dentition 3|3, with about eight small equal teeth per row. *Legs*: coxa I with two blunt teeth; coxae II–IV with a blunt external

tooth (arising from about the middle of coxa IV). Tarsi short and stout, sloping very abruptly; claws long; pad almost vestigial.

Female (Fig. 7): *Scutum* (1·5 × 2 mm.) cordate, ornate, with three light markings on a nearly black ground, the lateral markings sub-circular, the median marking linear. Punctation as in the ♂; emargination moderate. *Venter*: finely punctate; vulva between legs II and III; anal groove a semicircle; spiracle comma-shaped, but shorter and smaller than in the ♂. *Capitulum* as in the ♂ except for the porose areas which are circular with a narrow interval. *Legs* as in the ♂.

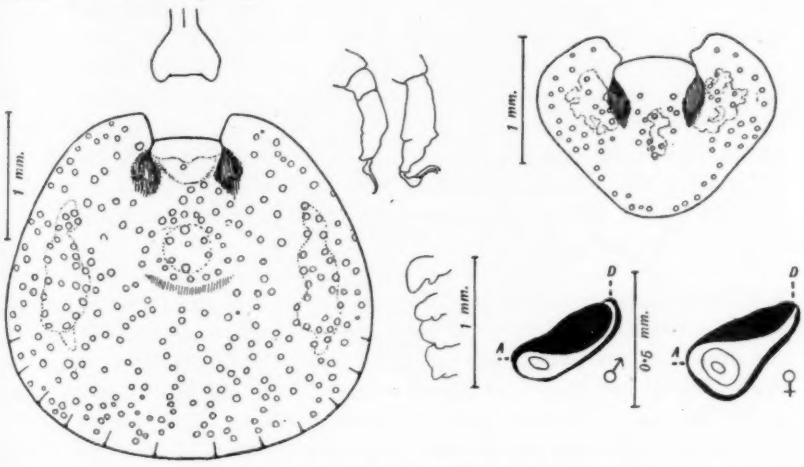

Fig. 7. *Aponomma draconis* n.sp. ♂ scutum, basis capituli, tarsi I and IV, coxae and spiracle. ♀ scutum and spiracle.

Described from 3 ♂♂ and 6 ♀♀ (in poor condition) taken from a "dragon," *Varanus komodoensis*, brought from Komodo Island, Flores, Dutch East Indies, and for some years past in the Zoological Gardens, London. Communicated by Dr P. A. Buxton, April, 1931.

Types in Cambridge (N. 3875).

Ornithodorus franchinii Tonelli-Rondelli 1930.

Dr Maria Tonelli-Rondelli (1930)[1] has described under this name a new Argasid tick taken in a hole in the Oasis of Gadames (Tripolitania) by Dr Lodato in 1927. In 1930 Prof. Franchini sent me specimens of the same tick with the intimation that it was being described by Dr Rondelli, and with the statement that it causes "tick-bite fever" in Cyrenaica and lives in all probability on small rodents in grottoes alongside rivulets. Dr Rondelli's figure—a half-tone photograph—gives an idea of the general facies of the

[1] *O. franchinii*, n.sp. un nuovo Argasidae della Tripolitania *Boll. de Zool.*, Anno I, N. 3, 1930, pp. 113–15, Naples, N. Jovene.

animal, but it fails to indicate the peculiar texture of the integument, and I give here (Fig. 8) a reproduction of a drawing in which this character is more apparent.

The validity of this fine new species is not in question, but its *generic* position raises a question of great interest. Dr Rondelli has missed its remarkable resemblance to *Argas brumpti* Neumann 1907. This resemblance is by no means superficial—one of size and general appearance—but extends to such characters as the armature of the legs, and apparently to the mode of life. Neumann's specimens were collected by Dr Brumpt at Ogaden in Somaliland (no host mentioned), and the severity of its bite is commented on at some length. We have received other specimens from Mr S. W. J. Scholefield who collected them from the dust of an ant heap in the Yatta Plains, British East Africa. He states that the natives, who call it Kituñu, believe that it feeds on large animals—elephant, buffalo, eland and giraffe. They also mention rock-rabbits, but Scholefield says these do not occur on the plains, and that on the hills *O. savignyi* abounds, and may very likely have been confused with *A. brumpti*. "*A. brumpti* is said to be always obtainable in the dust where big game rolls."

Now *A. brumpti* Nn. always appeared to me a somewhat doubtful *Argas*. With its projecting hood and its leg armature it had the general facies of such an undoubted *Ornithodorus* as *O. lahorensis* or *O. turicata*, but it did possess one *Argas* characteristic—a faintly distinguishable border of different texture to the general integument. I always regarded it as a link between the two genera, to either of which it might have been attributed. And here we have a form so like *A. brumpti* that it seems impossible to consider them generically distinct, but it is without the only remaining *Argas* character of that species; *O. franchinii* has an integument showing no differentiation of texture along the sides, though the hood shows some indication of being bordered. I should hesitate to say that *Argas* and *Ornithodorus* ought to be combined into one genus. There are many cases in which it is convenient to retain distinct names for groups of animals which in fact shade off into one another (*Rhopalocera* and *Heterocera* for example), and this is very likely such a case. The alternative course, which I think should be pursued, is to remove *A. brumpti* from the genus *Argas* and place it in the genus *Ornithodorus*.

Haemaphysalis cooleyi Bedford 1929

In the 15*th Annual Report of the Director of Veterinary Services of the Union of South Africa* (October, 1929, p. 494), Mr G. H. A. Bedford describes a new *Haemaphysalis—H. cooleyi*—from specimens taken by himself and Prof. Cooley on *Procavia capensis coombsi* Roberts, (the Transvaal "dassie") near Onderstepoort in August, 1928. The brief description and apparently very diagrammatic figures suggested a remarkably featureless form, with mainly negative characteristics. Mr Bedford was kind enough to send me in March, 1932, three ♂♂ labelled "*Procavia coombsi* Rbts, Onderstepoorte 5. vi. 31,"

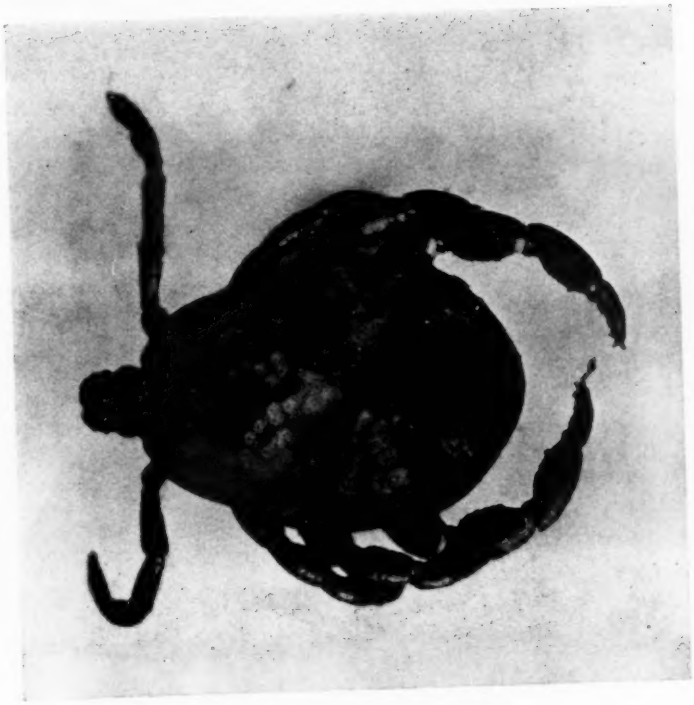

Fig. 9. *Rhipicephalus maculatus* Nn.

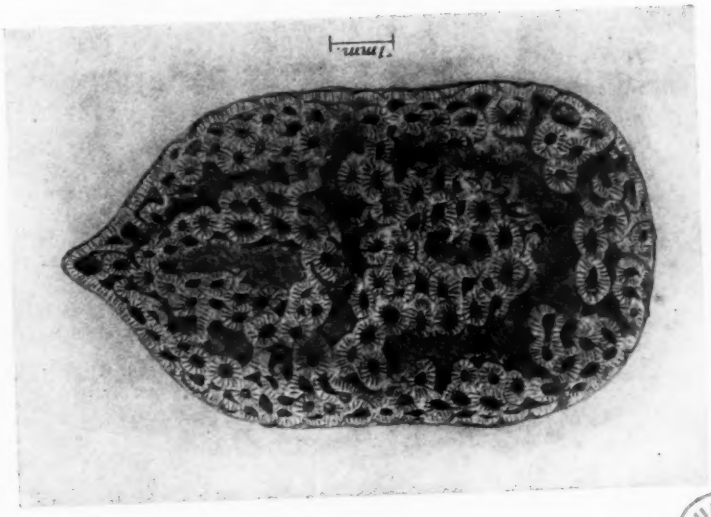

Fig. 8. *Ornithodorus franchinii* Tonelli-Rondelli. Dorsum.

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from the examination of which I am able to supplement his description in the following respects:

H. cooleyi Bedford.

Male: body rather narrow in front, broadest at the posterior third. *Scutum*: cervical grooves almost linear and converging; lateral grooves fairly well marked and including the first festoon. Festoons feebly marked. The punctation is fine and shallow, and does not prevent the scutum from appearing glossy. *Capitulum*: basis trapezoidal, broadest in front. The lateral salience of article 2 of the palps is marked off by a constriction not shown in Mr Bedford's figure. The ventral process of article 3, mentioned in the description as present in the ♂, and presumably therefore also in the ♀, does not appear in Mr Bedford's figure 3 c. *Venter*: the spiracle is a narrow transverse oval, with the narrower end dorsal. *Legs*: the coxae are almost unarmed, the inner angles being blunt and hardly observable. Trochantal spurs absent. Tarsus IV short and thick, tapering very abruptly, almost humped. Pad small.

I have not seen the ♀ nor the immature forms. From the ♂ it is clear that the characteristics upon which one is able to seize are indeed few: no dorsal spines on the palps, very feeble coxal armature, etc. In such a case very careful drawings of any structures which are at all distinctive seem essential.

Before I had received Mr Bedford's specimens I was engaged in examining a large collection of African ticks submitted to me by Prof. R. A. Cooley of Montana, U.S.A., and his catalogue stated that tube 172 contained a new species of *Haemaphysalis* which Mr Bedford was describing and naming after Prof. Cooley. Now the specimens in this tube, 1 ♂ and 1 ♀, did not at all agree with Mr Bedford's description. They were, in fact, examples of an already known species *H. numidiana* Nn. 1905. The label in the tube stated that the ticks were taken from *Pedetes caffer* Pall. (Spring hare) on October 1st, 1928. Now in Mr Bedford's description of *H. cooleyi* he states that the adults were taken on *Procavia capensis coombsi* on August 22nd, 1928, and that "several engorged nymphs and larvae were taken off *Pedetes caffer* Pall. at Pienaars River, Transvaal on October 1st, 1928 (coll. Prof. R. A. Cooley)." In view of the fact that the ticks in the collection submitted to me by Prof. Cooley as taken on *P. caffer* on October 1st, 1928, were *H. numidiana*, a doubt arises as to whether Mr Bedford was justified in attributing the nymphs from *Pedetes* to his new species which he obtained from *Procavia*.

Rhipicephalus maculatus Neumann 1901.

In 1901 Neumann described *R. maculatus* from a ♂ and 2 ♀♀ in the Berlin Museum, taken in the Cameroons on *Platymeris horrida*. Unfortunately no figure was given. Its general resemblance to *R. pulchellus* was noted, and its ornamentation described as consisting of a large number of detached yellowish spots.

We have received at Cambridge from time to time specimens which we have attributed—with some hesitation—to this species, but in all the dorsal pattern has been very fragmentary, and in 1912 I discussed the matter (*Parasitology*, **5**, 17) and gave a figure of a specimen in which the dorsal pattern was most complete.

Recently we have received from Mr E. Aneurin Lewis of Uganda specimens which we believe to reveal the true ornamentation of this fine species, and we give here (Fig. 9) a microphotograph of one of the males. The spots hitherto observed in specimens that have been attributed to this species all fall into place in the complete pattern, and the resemblance to *R. pulchellus* is increased.

Curiously enough, we have recently received from Prof. Franchini a variety of *R. pulchellus* from Italian Somaliland (host unrecorded) in which all the white markings were obsolete except patches on the scapulae, though the same consignment contained intermediate forms clearly linking these up with full-patterned specimens. In all previously received consignments of the exceedingly common *R. pulchellus* no variation in design of ornamentation had been observed, the pattern being always vivid and well marked, but in view of the above facts it is impossible to exclude the possibility of the two species having been confounded when the pattern was largely obsolete.

According to Neumann, while the legs of *R. pulchellus* are ornate, those of *R. maculatus* are uniformly brown, and in cases of obsolescent pattern this would appear to be the best character on which to separate the two species.

(*MS. received for publication* 19. VIII. 1932.—Ed.)

THE EXPERIMENTAL TRANSMISSION OF ANAPLASMOSIS BY *DERMACENTOR ANDERSONI*.

By CHARLES W. REES, Ph.D.

Zoological Division, Bureau of Animal Industry, U.S. Department of Agriculture (Jeanerette, Louisiana).

I have previously reported (1930) upon the experimental transmission of anaplasmosis by *Rhipicephalus sanguineus*, and (1932) *Dermacentor variabilis*. A preliminary report (Hall and Rees, 1932) has also appeared which incriminates *D. andersoni* as a carrier. The present paper gives a detailed account of the experimental evidence bearing on this vector.

Methods.

The barn at Jeanerette and other equipment whereby experimental control was effected have been described by me (1930, 1932) elsewhere. The procedure consisted in allowing ticks in one stage of the life cycle to engorge on one or more bulls with clinical anaplasmosis, and in the next stage to engorge on two susceptible bulls. As in the experiments previously reported, susceptible northern bulls were used as controls; none of the controls became infected. Nymphs which became infected as larvae, and adults which became infected as nymphs, transmitted the disease to susceptible bovines. The larvae derived from adult females engorged on clinical cases failed to transmit the infection, as is the case when *Boophilus annulatus* transmits piroplasmosis. The transmission experiments were carried out under the same conditions as those with *D. variabilis* previously reported by me (1932).

Failure of "hereditary transmission" in *D. andersoni*.

Dr R. R. Parker of the Rocky Mountain Spotted Fever Laboratory at Hamilton, Montana, kindly sent about 60 live adult *Dermacentor andersoni* ♂♂, ♀♀, which arrived at Jeanerette on October 22nd, 1931. These were divided into three approximately equal lots, *a*, *b* and *c*.

Lot a was allowed to engorge on bull no. 62 on October 26th. Anaplasmosis had been transmitted to this bull by the nymphs of *D. variabilis* by me in 1932 (*loc. cit.*), the clinical reaction beginning on September 2nd, 1931, and continuing until about September 20th. On October 16th the bull was splenectomised and a second reaction to anaplasmosis occurred on October 19th and continued during the period of engorgement of the adult *D. andersoni*. The following data relate to the second reaction of bull no. 62.

October 19th:	16	infected	erythrocytes	per 1000
„ 20th:	58	„	„	„
„ 21st:	60	„	„	„
„ 23rd:	95	„	„	„
„ 24th:	270	„	„	„
„ 27th:	80	„	„	„

Two fully engorged *D. andersoni* ♀♀ dropped from bull no. 62 on November 4th and 5th. These were kept in the laboratory where they oviposited.

Lot b were placed on bull no. 67 on November 2nd. This bull had reacted to anaplasmosis from September 4th to about September 24th, and, as in the case of bull no. 62, was a recovered carrier of anaplasmosis induced by *D. variabilis* when the adult *D. andersoni* were placed upon it. Two engorged ♀♀ of this species were removed from the bull on November 11th.

Lot c was placed on a heifer no. 76, during an attack of anaplasmosis which was transmitted to her by nymphs of *Rhipicephalus sanguineus*. The heifer died on November 9th before the *D. andersoni* ♀♀ were fully engorged and none of them oviposited.

Both egg masses hatched from the two female ticks (Lot *a*) that engorged on bull No. 62, and on December 14th many of the larvae were transferred in a bag to the scrotum of a susceptible bull no. 85. Of the two egg masses from the two female ticks (Lot *b*) that engorged on bull no. 67, only one mass hatched and the larvae so obtained were transferred on December 14th to the scrotum of a susceptible bull, no. 86. From December 19th to 22nd many engorged larvae were recovered from each bull.

Neither bull no. 85 nor no. 86 reacted to anaplasmosis, although these were susceptible animals, since on February 9th, 1932 (v. *infra*), the bulls were exposed to adults of *D. andersoni* and they reacted to anaplasmosis after about 30 days.

Transmission by nymphs of *D. andersoni*.

Many of the unused larvae from bulls nos. 62 and 67 were permitted to engorge on bull no. 66 on December 10th, 1931. This bull had clinical anaplasmosis, having been inoculated with virulent blood from bull no. 67 on November 23rd and having reacted on December 10th. Many engorged larvae were recovered from December 16th to 20th, and moulted in the laboratory to nymphs. On January 4th, 1932, these nymphs were divided into two lots and permitted to engorge on bulls nos. 87 and 88. On January 11th–12th, 28 engorged nymphs were taken from bull no. 87, and 80 engorged nymphs from bull no. 88. Bull no. 88 reacted to anaplasmosis on February 2nd, and no. 87 reacted on February 3rd. The incubation periods were, therefore, not longer than 28 and 29 days respectively. The clinical reaction, in so far as this could be determined by the temperature record and the microscopic study of smears, continued in each bull until about February 15th. Active erythrocyte regeneration, which was indicated by many normoblasts, occurred in bull no. 88

on February 9th and in bull no. 87 on February 11th. The Anaplasma count in each bull did not at any time exceed 110 per 1000 erythrocytes. However, while the clinical picture, as measured by the above methods, appeared to be about the same in each bull, no. 88 lost much more flesh and his general condition indicated a much more severe reaction than occurred in no. 87. Had it been practicable to record daily the weights of each bull, this last statement would have been strikingly illustrated. Both bulls made uneventful recoveries.

Transmission by adults of *D. andersoni*.

On January 4th, 1932, many nymphs of *D. andersoni* which developed from larvae that engorged on bulls no. 85 and no. 86 were available, and these were permitted to engorge on bull no. 68. This bull, no. 68, had been used on July 13th to 20th, 1931, in the test of hereditary transmission by *D. variabilis* (Rees, 1932) and failed to react. His susceptibility was, therefore, checked by intravenous injection of virulent blood from bull no. 62 on October 24th. Bull no. 68 reacted on November 6th, passed successfully through the attack, and was splenectomised on December 17th, so that on January 4th, 1932, the time of the above-mentioned engorgement of the nymphs of *D. andersoni*, a second clinical attack was in progress. In so far as could be shown by microscopic study, this second attack was somewhat more severe than the first attack, about one-fifth of the erythrocytes of the peripheral blood becoming infected on January 6th. Engorged nymphs were removed from January 11th to 14th and moulted in the laboratory to adults. On February 9th about 50 of these adults, males and females, were transferred to the scrotum of bull no. 85 and another 50 to bull no. 86. From February 17th to 20th, 16 engorged females and 20 males were recovered from bull no. 85, and 24 engorged females and 23 males were recovered from bull no. 86. Bull no. 86 reacted to anaplasmosis on March 10th, and no. 85 on March 11th. The incubation periods were, therefore, about 30 and 31 days respectively. The reaction in bull no. 85 was very mild. His temperature (afternoon reading) did not at any time exceed 103° F., and no symptoms other than the occurrence of Anaplasma were detectable. The reaction in bull no. 86 was severe. His temperature chart gave readings above 105° F. for several days, and about one-fifth of the erythrocytes of the peripheral blood became infected. The bull also lost condition rapidly and refused to eat for two days during the crisis which began about March 16th. Both bulls nos. 85 and 86 were used for experiments in the treatment of anaplasmosis with drugs, and additional details concerning them will, therefore, be published later.

Discussion.

In my experiments the engorged larvae, nymphs and adults of *D. andersoni* were kept in a cupboard in the dark over moist sand in 8 oz. specimen jars, the mouths of which were covered by muslin. On cool nights a 60-watt electric lamp bulb was kept lighted on the shelf beneath the ticks; at other times they were maintained at room temperature which was usually about 25° C.

According to Cooley (1928), the newly hatched larvae and the newly moulted nymphs should not be applied to their prospective hosts for at least several weeks, at the end of which time they should be incubated at about 30° C. for several days and then subjected for a time to a temperature of about 6° C. However, at this laboratory the larvae and the nymphs were transferred to the bovine's scrotum as soon as they were noted in the vials and, as is shown in the foregoing paragraphs, engorgement was very satisfactory. Only about 20 per cent. of the adult females that were received directly from Montana engorged. On the other hand, of those adult females that were reared in this laboratory and were applied to the scrotum of bulls Nos. 85 and 86 about 64 per cent. and 100 per cent. respectively engorged. General statements occur in the literature to the effect that in nature the larvae and the nymphs of the Rocky Mountain spotted fever tick engorge only on rodents. Thus, according to Cooley (1928): "If once started ticks can find more or less favorable conditions wherever rodents occur as hosts of the early stages and large animals whether wild or domestic as hosts of the adult ticks."

It was demonstrated, however, by Hooker, Bishopp and Wood (1912) at Dallas, Texas, that the immature stages will engorge on bovines, and my experiments at Jeanerette, Louisiana, confirm this. Nevertheless, *D. andersoni* does not occur in nature in either of these localities, although rodents and large animals are numerous. Therefore, the factors which limit the distribution of this species of ticks are yet to be discovered. In the Rocky Mountain district the larvae and nymphs may be found to be prevalent in the corrals and on the feeding grounds where cattle are kept, and the statement that they engorge in nature only on rodents must be regarded as a statement of our present state of information and subject to possible modification by future findings.

I have emphasised (1930) the well-known fact that, in the development of three-host ticks from larvae to adults, "We have a descending scale of numbers and an ascending scale of sizes with the progress of time. There will be enormous numbers of small seed ticks extremely difficult to see, a much smaller number of nymphs, larger in size but still difficult to find on animals, and especially when scattered over the large bodies of cattle, and finally a much smaller number of adults of which about half will be females, some of which will become engorged and can be readily detected."

The report by Hilts (1928) which showed that in Nevada an outbreak of anaplasmosis occurred in 35 out of 340 head of cattle that were dehorned without disinfecting the instruments in going from one animal to another, indicates that anaplasmosis occurs in the Rocky Mountain region. My results show that this disease may be experimentally transmitted by *D. andersoni*. Other reports from this laboratory and from many other parts of the world[1] indicate that ticks are vectors of anaplasmosis in nature. It has been pointed

[1] Starting with Theiler, A. (1910) *Anaplasma marginale* (gen. et sp. nov.), *Report Govt. Veter. Bact.*, Pretoria, 1908–9, p. 7, and (1912) Uebertragung der Anaplasmosis mittels Zecken, *Z. f. Infektionskr. der Haustiere*, **12**, 105–116, in South Africa.—(Ed.)

out by Hall and Rees (1932) that the incrimination of three species of ticks, viz. *R. sanguineus*, *D. variabilis* and *D. andersoni*, "establishes the possibility that anaplasmosis occurring anywhere within the known range of distribution of that disease in the United States may be tick-borne so far as a coincident distribution of known tick carriers can establish this possibility."

Furthermore, at least one of these three species of ticks occurs in every state of the Union and in the District of Columbia. This evidence warrants the serious attention of all who are engaged in dairying or in beef production because anaplasmosis may be spreading at the present time into new areas.

SUMMARY.

It has been determined that anaplasmosis may be transmitted by *Dermacentor andersoni* under the following conditions: (1) Larvae may acquire the infection by engorging on a bovine whose blood contains anaplasms and may transmit the infection as nymphs to susceptible bovines; and (2) in a similar manner the nymphs may acquire the infection and transmit it as adults. The test of "hereditary" transmission was negative, *i.e.* the larvae did not apparently acquire the infection from adult females which engorged on carriers of anaplasmosis. Conditions of transmission by *D. andersoni* are the same as those which have thus far been determined by me for *D. variabilis*. The incrimination of these two species of tick points to the possibility that anaplasmosis occurring anywhere within the known range of distribution of that disease in the United States may be tick-borne so far as a coincident distribution of known tick carriers can establish this possibility.

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COCCIDIOSIS IN RACCOONS: *EIMERIA NUTTALLI* N.SP., PARASITE OF *PROCYON LOTOR*.

By Professor W. L. YAKIMOFF, D.M., D.V.M., and I. L. MATIKASCHWILI, *Veterinarian*.

From the Parasitological Laboratory, Veterinary School, Leningrad.

(With 1 Figure in the Text.)

The following Carnivora are known to be parasitised by Coccidia:

Family and species	Parasite
I. Mustelidae	
Mustela (*Putorius*) *putorius* (polecat)	*Isospora bigemina* var. *putorii* (Railliet and Lucet 1891)
Mustela (*Putorius*) *putorius* var. *furo* (ferret)	*Isospora laidlawi* Hoare 1927
" "	*Eimeria ictidea* Hoare 1927
" "	*Eimeria furonis* Hoare 1927
Mephitis mephitica (skunk)	*Eimeria mephitidis* Andrews 1928
Martes zibelina (sable)	*Eimeria siberica* Yakimoff and Terwinsky 1931
II. Canidae	
Canis familiaris	*Isospora bigemina* var. *canis* Railliet and Lucet 1891
"	*Isospora rivolta* Grassi 1879
"	*Eimeria canis* Wenyon 1923
Vulpes vulpes (fox)	*Eimeria vulpis* Galli-Valerio 1929
"	*Isospora vulpis* Galli-Valerio 1931
Canis (*Vulpes*) *velox* (swift fox, America)	*Isospora canivelocis* Weidman 1915
Canis (*Vulpes*) *fulvus* (silver fox, America)	" " "
Alopex lagopus (polar fox)	*Eimeria mesnili* Rastegaïeff 1930
Canis aureus (jackal)	*Isospora theileri* Yakimoff and Lewkowitsch 1932
III. Felidae	
Felis felis (domestic cat)	*Isospora bigemina* var. *catti* Railliet and Lucet 1891
" "	*Isospora rivolta* Grassi 1879
" "	*Isospora felis* Wenyon 1923
" "	*Eimeria felina* Nieschulz 1924
Felis leo	*Eimeria felis* Wenyon 1923
Felis tigris	*Eimeria novowenyoni* Rastegaïeff 1930
"	(? Genus) *hartmanni* Rastegaïeff 1930
Felis eyra	*Isospora rivolta* Grassi 1879
Lynx lynx	*Isospora felis* Wenyon 1923
IV. Viverridae	
Viverra civetta	*Isospora viverrae* Adler 1924

To the foregoing list we are able to add: V, Procyonidae, from which Coccidia have not hitherto been recorded:

Eimeria nuttalli n.sp. (Fig. 1).

Early this year (1932) we examined eight American raccoons (*Procyon* s. *Notocyon lotor*) whose faeces, according to Darling, contained Coccidia of our species.

Description. Oocysts oval. Membrane double contoured; external layer thicker than the internal (1·3–1·65 μ). No micropyle nor cap were detected.

At times the oocysts contained a polar granule as in the Eimerias of fowls (*E. tenella*, *E. mitis*, *E. acervulina* and *E. maxima*).

Size (50 oocysts measured). The largest specimens measured 23 × 16 μ, the smallest 16·5 × 13·2 μ. The average size was 19·5 × 14 μ, but most of them measured 21·6 × 14·3 μ. The *shape index* was 1 : 0·63–0·88; average 1 : 0·67; mostly 1 : 0·68.

Sporulation occurred when the faeces were placed in a 2·5 per cent. solution of potassium bichromate. The four spores were oval and measured 7·5–8·8 × 5·5–6·6 μ and appeared as shown in Fig. 1.

We regard the parasite as a new species and name it as above in honour of Prof. G. H. F. Nuttall the parasitologist.

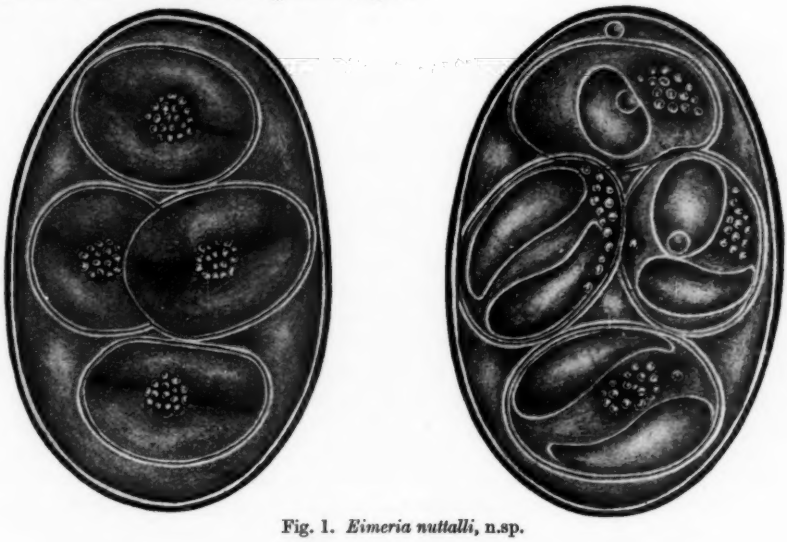

Fig. 1. *Eimeria nuttalli*, n.sp.

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